SCIENTIFIC AMERICAN MONTHLY

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SCIENTIFIC AMERICAN MONTHLY
Edited by A. RUSSELL BOND
Published Monthly by Scientific American Publishing Co. **Munn & Company, 233 Broadway, New York, N. Y.**
Charles Allen Munn, President. Orson D. Munn, Treasurer. Allan C. Hoffman, Secretary, all at 233 Broadway
Scientific American Monthly . . . per year $7.00 **Scientific American (established 1845) . . . per year $6.00**
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application
Remit by postal or express money order, bank draft or check
(Entered as second class matter, December 15, 1887, at the Post Office at New York, N. Y., under act of March 3, 1879)
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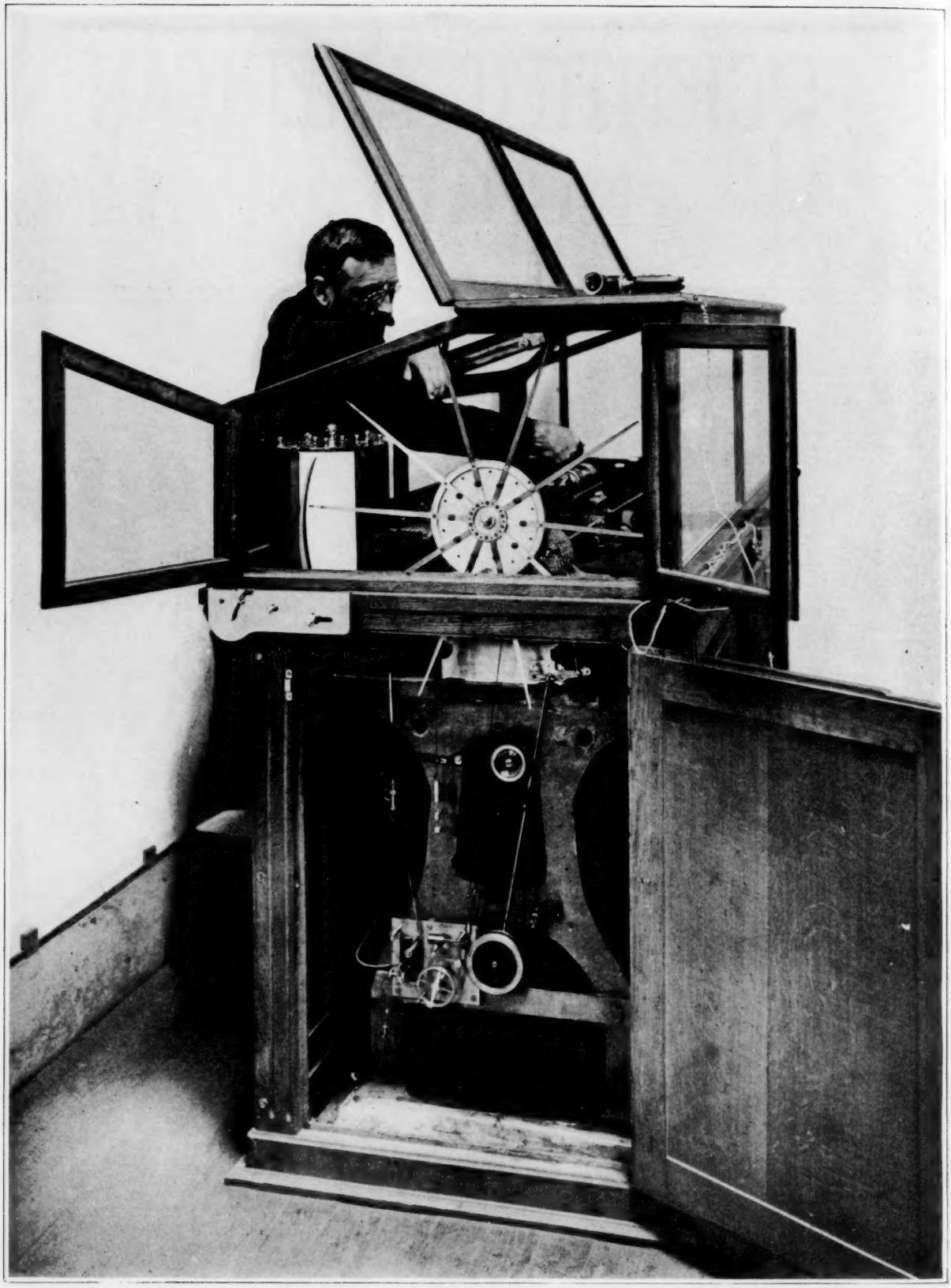


THE INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES—COMPARING END STANDARDS FOR ENGINEERS' MEASUREMENTS WITH THE HARTMANN COMPARATOR (SEE P. 105)

SCIENTIFIC AMERICAN MONTHLY

VOLUME III
NUMBER 2

NEW YORK, FEBRUARY, 1921

60 CENTS A COPY
$7.00 A YEAR

THE EINSTEIN AWARD

OUR readers will remember that in July of last year Mr. Eugene Higgins offered, through the SCIENTIFIC AMERICAN, a prize of the extraordinary amount of $5,000 for the best popular essay on the Einstein Theories of Relativity. The contest aroused wide interest, and a wide response. Essays were received from all parts of Europe and North America, from India and South Africa and South America. When the contest closed on November 1st there were in the hands of the Einstein Prize Essay Editor exactly 300 essays.

With such assistance as it was proper for the Einstein Editor to extend them, the judges, Drs. Leigh Page of Yale and E. P. Adams of Princeton, have since this date been working their way through this mass of material, eliminating essays as fast as possible, and gradually approaching the ultimate goal of a single survivor. This goal has at length been reached; in the issue of the SCIENTIFIC AMERICAN which is current when this number of the MONTHLY goes to its subscribers, the long-looked-for announcement is made that the prize has been won by Mr. L. Bolton, of London. Mr. Bolton's essay will be printed in the SCIENTIFIC AMERICAN for February 5th.

The choice of one essay out of 300 at the best is an undertaking which must in large measure reflect the personal taste and the personal opinion of the one who undertakes the choice. With this in mind, it had hardly been our hope that the judges would agree upon a winning essay; we had been quite prepared for the necessity of the Einstein Editor's being called upon to decide between their respective preferences. We need not say that the ability of the judges to agree upon a winning essay without this step has been a source of extreme gratification to us.

It will be understood that the whole purpose of Mr. Higgins in offering this prize, and of the SCIENTIFIC AMERICAN in sponsoring the offer, was by no means the elicitation of a single "best" essay. The other 299 essays in their entirety must necessarily make a contribution to the literature of the subject which is second only to that made by the winner, or which might even conceivably be of such value as to make the winning essay second to it. Viewed from the standpoint of the completeness with which the totality of the competing essays covers the field of Relativity the present contest has been a notable success. In variety of treatment and in diversity of material the essays are all that could have been hoped for.

In the SCIENTIFIC AMERICAN MONTHLY for March we shall present one of the essays—the one which is at once the winner's closest competitor and the best suited of the leading dozen essays for a position here in preference to one in the SCIENTIFIC AMERICAN itself. This will be followed, in subsequent issues both of the SCIENTIFIC AMERICAN and of the SCIENTIFIC AMERICAN MONTHLY, by further essays.

A NEW ASTRONOMICAL MARVEL

STRANGE as it may seem the largest object ever measured was scaled off with the minutest of measures known to science, and it but adds to the paradox to state that the measurement, while the most stupendous ever undertaken, was at the same time the most infinitesimal. The object which was the star Betelgeuse in the constellation of Orion, turned out to be some three hundred million miles in diameter and the unit of measurement employed was half a wave-length of light.

Now to the vast majority of us, a hundred million miles conveys little meaning and a wave length of light even less. Nor does it help us much to be told that the average solar light wave measures about 0.00002 inch in length. This length is so infinitely small that we cannot begin to visualize it. In former days a hair's breadth was rated as the very acme of tenuity. It is a very fine human hair that measures two one-thousandths of an inch in thickness. Now take that hair and split it into a hundred slivers, and we shall find that each sliver is equal in thickness to the length of a single wave of light. In other words, a ray of light makes one hundred vibrations in traversing a space of the breadth of a fine hair and when we consider that the ray is traveling at a rate of 186,000 miles per second, we must admit that the frequency of these vibrations far surpasses our powers of conception.

However at present we have to deal not with the frequency of the oscillations, but with their length. In fact it is only half a wave-length that is used as our unit of measure; in other words, the one-hundredth part of half a hair's breadth.

Of course it was not the actual diameter of Betelgeuse that was measured, but the minute angle formed between two rays starting from opposite sides of the great star and coming together in our telescope. Just how this angle was measured is explained very clearly by Professor Russell's article in the following pages. The angle worked out to forty-five one-thousandths of a second of arc; in other words, the rays are so nearly parallel that they would not show a spread of a hair's breadth in 250 yards and we should have to travel back along the rays for a distance of over 70 miles before we should reach a separation of one inch. Of course the farther we trace these rays, the greater the separation until eventally we arrive at their source where of course their separation equals the diameter of the star. Hence, if we know the distance of the star from our telescope, we can determine its size.

Unfortunately Betelgeuse is so remote from us that it is exceedingly difficult to measure its distance with any degree of accuracy. According to the latest estimates, it is probably well over 200 light-years distant from us and its diameter must therefore be about 350 times that of the sun.

Measuring the Diameter of the Stars

Recent Astronomical Applications of Professor Michelson's Interferometer

By Henry Norris Russell

Professor of Astronomy at Princeton University

VISITORS to an observatory, who have enjoyed a look at one of the planets, and have seen how large it appears under the magnifying power of the eyepiece, are very likely to ask next to be shown a star, anticipating that it also will appear as a visible disk. When the telescope is turned on a bright star, they are usually much surprised by what they see. The brilliance of a conspicuous star, when its light is concentrated by a large telescope, is spectacular enough to satisfy pretty lively anticipations; but the novice is prone to amazement when he finds that, though it appears so much brighter, the star looks no bigger through the telescope than it does without it. Though its image may be surrounded by more or less "glare" (due to the scattering of light by dust on the lenses, or to minute imperfections in them) the actual image of the star itself is still a mere speck, without perceptible dimensions, though dazzlingly bright.

The trained observer, however, who notices finer details, will see, under a high magnifying power, that the telescopic image of the star is not really a mathematical point, but a tiny circular disk surrounded by concentric luminous rings, separated by dark intervals, and each farther than the last, so that only a few are visible unless the star is very bright. This singular pattern appears of the same size and similar in all its details, whatever be the star upon which the telescope is turned; and this part alone might lead us to suspect that its appearance was due to some property of the telescope, and not of the stars. If our telescope has an iris diaphragm before its objective, we may at once change this suspicion into certainty. As the diaphragm is narrowed, and the clear aperture, through which the star's light enters the telescope is diminished, the pattern of disk and rings will be seen to expand, reaching double its original diameter when the opening of the diaphragm is reduced to half its initial size. This "spurious disk" is not due to any imperfection in the construction or adjustment of the telescope, but arises—as we shall see more fully later—from the very nature of the waves of light. No optical device whatever can get rid of it absolutely, but there is one effective, but very expensive, method of diminishing it, namely, to increase the size of our telescope. The astronomer measures the diameter of this spurious disk, just as he would measure that of a real disk which looked equally big, in seconds of arc; and its diameter, measured in this way, is inversely proportional to the aperture of the telescope. For a clear opening one inch across the spurious disk is 4″.5 in diameter; for a telescopic aperture of one foot, it is 0″.38, for the Yerkes 40-inch telescope 0″.11, and for the 100-inch at Mount Wilson a little less than 0″.05. The "resolving power" of a telescope—that is, its power of revealing minute detail—is therefore proportional to the available aperture of the instrument.

A close double star, in which the components are half a second of arc apart, cannot be seen double with a six-inch telescope, for in such an instrument the spurious disks are 0″.75 in diameter, and overlap one another—though a thoroughly experienced observer might detect that the image formed by the two overlapping disks was slightly oval. With a 12-inch telescope the same pair would be easily separated; but to resolve a closer pair—say, of separation 0″.45—would require an aperture of 30 inches at least. Every increase of aperture reveals new double stars, which were irresolvable in smaller telescopes, and there are doubtless great numbers more of double stars so close that no existing telescope can separate them.

The practical astronomer would however be happy indeed, if no other limitation than the one of which we have been speaking, affected his observations. But, alas, he has to look through fifty turbulent miles of the earth's atmosphere. Even under the best conditions, the rays of light which enter his telescope have been more or less deviated in their courses by refraction in passing from one layer of air to another, and, in consequence, the diffraction pattern of disk and rings, which can be so clearly and beautifully shown in the laboratory, oscillates, trembles, and is more or less confused and distorted. Under more ordinary and worse conditions of "seeing" the image is more disturbed and dances about, coming only occasionally to rest, and it is during these favorable intervals alone that close pairs of stars can be seen double. On many nights, indeed, when the sky is cloudless, but the air windy, and full of streaks of varying density and temperature (the airman's "bumps") the stars twinkle furiously, and their telescopic images are so blurred that accurate observation of any sort is impossible.

Unfortunately, too, a given amount of atmospheric disturbance affects a large telescope much more than a small one, for the large instrument looks through a wider column of air, in which there is greater chance of meeting with optical disturbances. With such an instrument, it is decidedly rare to find a night on which the seeing is really satisfactory—even in those favorable localities which have been chosen as sites for modern observatories.

It is clear from the foregoing how welcome it would be to astronomers to have some way of obtaining a high resolving power other than by building enormous and exceedingly costly telescopes, and also how great a boon it would be to escape, even in part, the annoyances and obstacles which arise from the turbulence of our atmosphere. Professor Michelson's most recent addition to the long list of his notable services to science has been to solve both these problems—and to win his success by the use of those very properties of waves of light which cause the appearance of the annoying spurious disk. The apparatus which he employs—the interferometer—is one which he designed many years ago, and has applied with notable success to the investigation of many other problems.

The fundamental principle which it involves is the separation of a beam of light, proceeding from a single source into two parts, and the recombination of these two beams in such a way that the light waves can "interfere" and produce a visible pattern of light and dark bands, or "fringes."

The manner in which these fringes is produced is the central feature of the whole affair, and is simple enough to understand, if we remember that light consists of "trains of waves in the ether." The light given out from luminous gas, like that in a nebula, consists of very regular and uniform oscillations, which repeat themselves at exactly equal intervals, in time and space, for thousands of successive vibrations. A hot body, such as a star, gives out a jumble of vibrations of all periods. But fortunately for the present purpose our eyes are sensitive only to vibrations including but a small range in period (especially when, as in the case of the stars, the light is fairly faint), so that we may ignore the other vibrations, whether more rapid or slower, and confine ourselves to those which are very near a certain average rapidity of vibration, or length of wave. These "waves" consist of changes in the electrical and magnetic condition of the ether, alternately on opposite sides of the undisturbed state. If then two waves, reaching the same point by different paths arrive so that they disturb the ether at the same instant in the same way (technically, if they arrive with the same phase) they will rein-

force one another, but if they arrive in opposite phases, the disturbances which the two produce will annul one another, and the two waves will "interfere."

In the simplest form of Michelson's recent apparatus, two slits S_1 and S_2 are made in a screen S set up in front of the mirror of a reflecting telescope as is shown in Fig. 1, which is a section of the apparatus at right angles to the direction of the slits.

The waves of light emitted from the star toward which the telescope is pointed are illustrated in the upper part of the figure by lines following successive "wave fronts" (that is, regions where the disturbance in the ether is at a maximum, and in the same phase). These wave fronts are really arcs of circles centered upon the star, but, for all practical purposes, we may treat them as straight. They advance at right angles to the wave front, as is shown by the "rays" $R_1 S_1$ and $R_2 S_2$ and impinge upon the two slits S_1 and S_2 at exactly the same instant and in the same phase. Being reflected from the mirror immediately behind they emerge again from the slits,

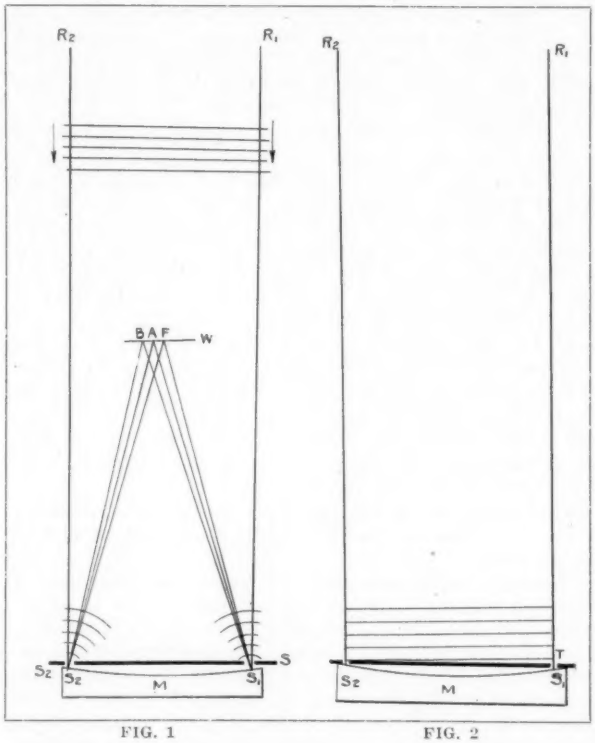


FIG. 1

FIG. 2

and, upon escaping from these narrow apertures, they tend to spread out, as illustrated by the circular wave-fronts drawn on the diagram.

If F is the focus of the mirror, the distances $F S_1$ and $F S_2$ will be equal and the two reflected waves, which started from S_1 and S_2 at the same instant, will take equal times on the journey and reach F together—and once more in the same phase. They will reinforce one another so that there will be plenty of light at F. If, however, we go sidewise from F to some other point, such as A or B, the distance from S_1 and S_2 will no longer be equal, and the two waves will not arrive at the same time. At some point A the difference of $A S_1$ and $A S_2$ will be half a wave-length and the disturbance coming from the nearer slit will be in advance of the other by half a vibration, so that the two will arrive in exactly opposite phases, and their effects will annul one another. Farther out, at B, where one of the two paths exceeds the other by a whole wave length, the first set of waves will have gained a whole vibration on the other and each disturbance from S_1 will meet with the one reflected from S_2 one period later in such a way that the two reinforce one another. Still farther out, where the path difference is 1½ wave-lengths, destructive interference will again occur and so on.

If then we should place a white screen W in the focal plane, we would see on it a bright region at F where the waves reinforce one another, a dark region at A (where they annul one another) a second bright region at B, and so on. In the direction parallel to the slits (and at right angles to the plane of the figure) these bright and dark regions would be drawn out into parallel lines or "fringes," alternately bright and dark.

These are the fringes which are used in the Michelson interferometer. Before proceeding to describe its applications, we may, in passing, use the principles which we have just studied to explain the formation of the spurious disk in an ordinary telescope.

Suppose that a large number of other intermediate slits in addition to S_1 and S_2 were made in the screen S, alternately, the whole screen would be cut away, leaving the mirror free, but in following the interferences of the light waves, we might still divide up the mirror surface into a great number of adjacent parallel strips, such as the slits would isolate.

At the point F the waves reflected from all these "elementary" strips will arrive together, in the same phase, and we will get universal reinforcement and a great deal of light. At A the waves coming from opposite sides of the mirror, at S_1 and S_2 will completely annul one another. The waves coming from paths of elements on each side, but nearer the center will, however, only partially annul one another (being out of phase by less than half a period) so that when all is added together the light, though weakened, will not disappear. But at B there is a difference of a whole wave between S_1 and S_2 and hence of half a wave between S_1 and the light reflected from a strip at the middle of the mirror.

The light reflected from these two strips will then interfere destructively. Similarly for any strip between S_1 and the middle of the mirror it will be possible to find a corresponding strip between the middle and S_2, such that the disturbances reflected from the two arrive in exactly opposite phases. If all the strips of the mirror were of the same length and hence reflected equal amounts of light the contributions of the successive pairs which we have described would annul one another, each for each, and no light at all would be seen at B. When the fact that the strips near the middle are longer than those near the edges is taken into account, it is found that there is still a faint illumination at B, but that the light disappears altogether at a point about twenty per cent farther away from F. Beyond this, though a larger part of the contributions reflected from the various strips cancel one another, there is a small unbalanced residue, and faint light reappears, to be succeeded by other dark regions of complete annulment, and by ever fainter ones of incomplete cancellation.

We would evidently reach a similar result if we went to the same distance from F in any other direction in the plane of the screen W (at right angles to that of the paper). Our interference pattern will therefore be this time a circular disk, surrounded by a dark rim, then by a faint ring of light, and so on—just as is seen in the telescope.

So far, in considering the production of the fringes, we have treated one star as if it were a mere luminous point. It is, however, in the modifications introduced into this simple theory, by considering the actual conditions, that the importance of the new method lies.

Consider first the case of a close double star, too narrow to be resolved by the telescope which is employed. If we point one instrument toward such a system, we will see, with the telescope alone, merely a single spurious disk formed by the superposition of the diffraction patterns of the two stars. Similarly, if we introduce the Michelson apparatus we will have two sets of fringes in view at once, and superposed.

If the telescope is pointed exactly at one star of the pair,

the light waves from this star will arrive at the slits S_1 and S_2 at exactly the same moment, and will produce fringes exactly as described above with the central bright fringe at F.

But the light waves from the other star will come down at a slightly different angle, as illustrated in Fig. 2, and each wave will reach one of the slits, say, S_2, a little earlier than the other. This retardation will be carried over into trains of reflected waves which emerge from the slits. If the difference of path, outside the slits, for the second star is half a wave length, the reflected wave trains will be out of step by half a period, and when they reach the point F, after traversing equal paths from S_1 and S_2, they will be in a condition to interfere, and there will be darkness instead of light at this point. On the contrary, the trains of waves arriving at A will be in phase with one another—the half wave gained on the shorter journey from S_2, combining with the half-period advance at S_2 to give a change of a whole period. The length of this star will therefore also form a system of fringes, spaced at the same interval as in the first case, but with a dark fringe instead of a bright one at the central point F, and, in general, bright fringes just where the dark fringes of the first system occur, and vice versa. Since the light of both stars enters the telescope at once, the two sets of fringes will be superposed and each will fill up the gaps in the other. If the two stars are equally bright, this compensation will be complete, and the whole field of view will appear uniformly illuminated. If one is brighter than the other the fringes will

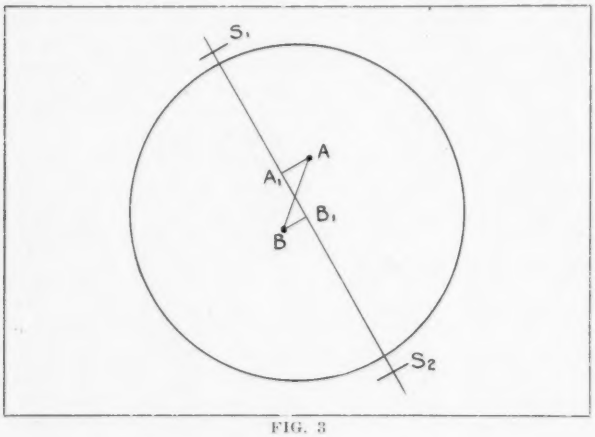


FIG. 3

not wholly disappear, but will become greatly reduced in contrast and "visibility."

If the additional distance through which the light of the second star has to travel to reach the remoter slit is more or less than half a wave-length, the two systems of fringes will be displaced relatively to one another by more or less than half an interval (as the case may be) and they will not completely compensate one another, even if the stars are equally bright. Indeed, if the path-difference for the second star amounts to a whole wave-length, its fringes will be shifted by a whole interval, and will reinforce the adjacent fringes due to the other star.

If the slits S_1 and S_2 were fixed we would therefore find it very hard to draw definite conclusions; but they are so mounted that they can simultaneously be turned toward or from the center of the mirror, and the distance between them can be changed at will. The path-difference for the second star (other things being equal) will evidently be proportional to the distance between the slits, and by altering this distance, we may readily find the position at which this difference is half a wave-length, and the fringes disappear (if the two stars are equal in brightness) or show a minimum of visibility if the stars are unequal. For a wider separation of the slits the fringes will reappear and reach a maximum of visibility, only to fade out again when the path-difference is 1½ wave-lengths, and the separation of the slits three times the initial setting (provided of course, that this greater distance is within the range of the instrument).

If α is the angular distance between the two stars, it follows by the most elementary trigonometry, applied to the triangle $S_1\ S_2\ T$ in Fig. 2 that $\text{Tan}\ \alpha = \frac{1}{2}\ \frac{\lambda}{S}$ where λ is the wave-length of the light (so that $S_1\ T = \frac{1}{2}\ \lambda$) and S is the distance $S_1\ S_2$ between the slits.

For sunlight, experiments made at Mount Wilson show that the effective average value of λ is 0.00055 millimeters, whence it follows, that the Michelson apparatus, with slits one foot apart, should detect the duplicity of a double star, by the vanishing of the fringes, if its separation was 0″.19. This is just half the minimum separation of the closest pair that could be seen double with the full aperture of a 12-inch telescope. It may seem paradoxical that we can increase the resolving power of the instrument by cutting down the openings into which the star light enters, but the reasonableness of our conclusion appears when we remember that we are now taking beams of the light from the two opposite sides of the objectives which show the greatest difference of path to a point near the focal image F, and cutting out the beams which come from the central point and show a smaller path difference and less tendency to interfere.

In the actual use of the apparatus the slits are mounted on a frame which may be rotated around the optical axis of the telescope so that the line joining them may be turned into any desired direction (position angle) in the field of view. If they are so set that this line is apparently parallel to the line joining the stars, the instrument is set in position to measure the angular separation of the stars. If on the contrary, the line joining the slits is at right angles, in the field of view, to the line joining the star images the light of the two stars will reach the slits at the same instant, and the fringes produced by the two will be superposed exactly no matter how far apart the slits are set. For intermediate settings the distance corresponding to the disappearance of the fringes will be less than the true separation of the stars, being in fact, the projection of this distance upon the line joining the slits ($A'\ B'$ instead of $A\ B$) Fig. 3.

By making use of this principle, the apparent direction of the stars from one another may be determined, as well as the distance.

In applying this instrument in practice we have now a notable advantage in that we do not have to "go it blind," testing one star after another until we hit upon a double one. There are many stars which we know from spectroscopic observations to be double. From the comparative intensities of the lines in the spectra, we know the relative brightness of the components; from the spectroscopic orbits we may determine their distance apart in meters or kilometers. When we know or can estimate the parallax of the system, we can then deduce the probable angular separation of the components in the sky.

In this way it appears that most of the spectroscopic binaries, especially the white stars of short period, such as Beta Aurigae must have angular separations so small that there is no hope of resolving them, even with Professor Michelson's apparatus. But in some cases things are more favorable and we can pick out the most promising cases. Best of all is Capella. This brilliant star, one of the most conspicuous in the sky, was shown long ago by Campbell's spectroscopic observations to consist of two nearly equal components, revolving about one another in a nearby circular orbit with a period of 104 days, and a separation of at least 52 million miles (and probably more, if the orbit was not turned edgewise forward us). From the known parallax of the star, it appeared certain that the separation was at least 0″.03 and direct observation with the Lick telescope showed that it must be less than 0″.08; for otherwise it could have been seen double, or at least "elongated."

Dr. Anderson, working at Mount Wilson with the apparatus designed by Michelson for the purpose, found on the very first trial that with a certain setting of the slits, the fringes could be made to disappear, while, when the slits were turned with a position angle 90° away, the fringes were clear and sharp. The general appearance of the fringes in the two cases is illustrated in Fig. 4 (taken from Dr. Anderson's published article and representing photographs obtained with an artificial double star in the laboratory. The image marked "86" shows the sharp fringes visible in the second position while that marked "36" illustrates how they vanish through su-

FIG. 4. APPEARANCE OF INTERFERENCE SYSTEM FROM ARTIFICIAL STARS IN THE LABORATORY

perposition, except near the edges of the field, where owing to secondary influences, one set predominates on the right and the other on the left. The intermediate edges show how small an angular shift of the line joining the slits suffices to alter the appearance of the fringes.

The most remarkable and encouraging fact of all remains to be told. It was found that "bad seeing" even if serious enough to interfere almost entirely with direct telescopic observation, had very little effect on the visibility of sharpness of the fringes. This was as unexpected as it was gratifying. The explanation appears probably to be that the deviations which the light waves undergo while passing through the air affect mainly the direction in which they travel rather than the time at which they reach a given point. This would account for the success of the interferometer even on poor

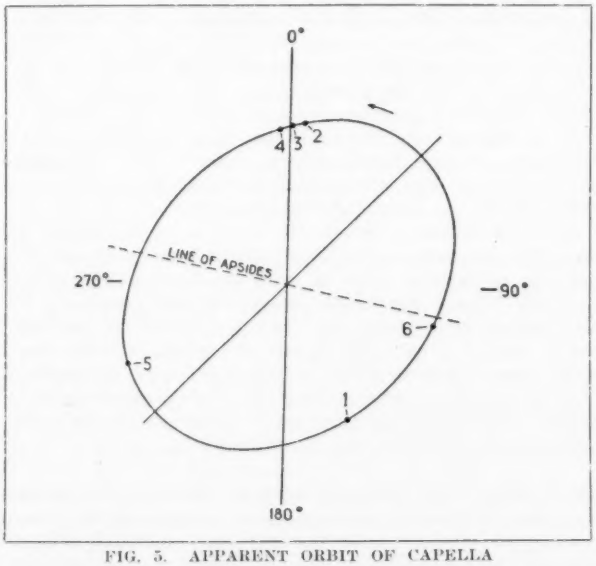


FIG. 5. APPARENT ORBIT OF CAPELLA

nights, but it may be that further study will be needed before the full explanation is attained.

Later observations agreed in indicating the duplicity of Capella, and showed the extraordinarily rapid motion of the stars around one another, amounting at times to 4° per day in position angle (4° a year is pretty fast for an ordinary double star)!

Fig. 5 (also from Anderson's paper) shows the apparent orbit of one star around the other, with the six observations plotted upon it. The plotted points fall almost exactly upon the curve, indicating that the measures are very accurate. The entire interval between Observations 1 and 6 (covering more than a whole period) was less than four months (before December 30, 1919 and April 23, 1920). The maximum angular separation for Observation 5 was 0″.050—one-twentieth of a second of arc, corresponding to the apparent angular size of one inch at a distance of 65 miles.

From these observations, combined with those already obtained with the spectroscope, it is computed that the main distance between the components of Capella is 81,300,000 miles; that the masses of the two stars are 4.6 and 3.6 times as great as the sun's mass, and that the parallax of the system is 0″.060, corresponding to a distance of 54 light years.

Not content with this brilliant success (which indeed was regarded almost as a by-product of the main investigation, or at least as an easy test to show the practicability of the method) Michelson has proceeded to attack the far more difficult problem of measuring the angular diameters of the fixed stars.

The additional troubles here are two-fold: first the apparent diameters of the stars are very small indeed, and second, it is a much harder matter to observe the disappearance of the fringes in the case of light coming from a luminous disk than

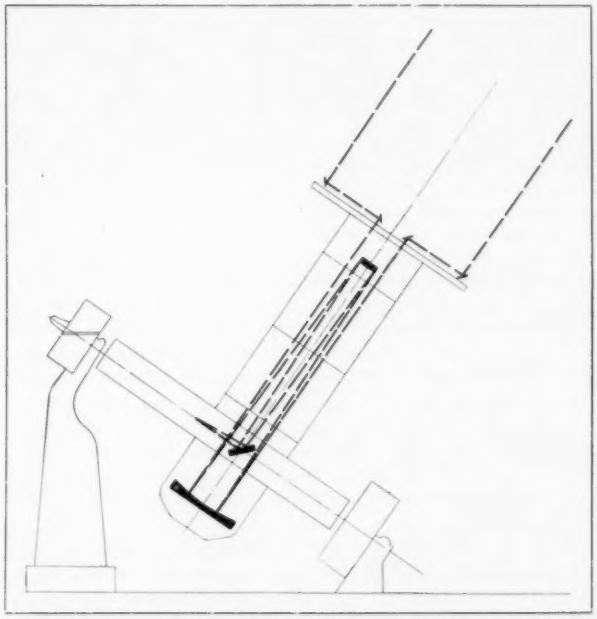


FIG. 6. INTERFEROMETER WITH SPREAD OF 20 FEET BUILT ON THE 100-INCH TELESCOPE AT MT. WILSON

from two isolated stars with a separation equal to the diameter of the disk. In the former case the light from the middle of the disk complicates the situation and the slits have to be set more than twice as far apart to make the fringes vanish.

To get around this second difficulty, Michelson and Hale adopted the bold course of building an interferometer with a spread of twenty feet as illustrated in Fig. 6.

A long steel beam, attached to the outer end of the 100-inch telescope carries a pair of mirrors which can be moved outward or inward and set at any desired distance. A second pair of mirrors inclined like the first at 45°, reflect the light to the great mirror of the telescope, after which it follows the ordinary path, being reflected back toward the eye-end, and finally sideways to a convenient point for observation.

So far as the optical effects are concerned the distance between the outer mirrors is the equivalent of the distance of the slits in the simpler apparatus.

The first difficulty can best be diminished by a proper choice of stars. The brightest stars, of course, are sure to have the largest apparent diameters—other things being equal—but other things are not equal in the least. White stars are

doubtless far hotter than yellow stars like the sun, and these again hotter than red stars; and the hotter a star is the brighter it shines per square mile of surface. If all the stars could be heated or cooled, keeping the size of each one unaltered till their surface temperatures were the same as that of the sun, white stars, like Sirius or Vega would lose most of their light, while red stars would be greatly increased in brightness. We cannot perform so colossal an experiment on the stars of heaven; but, from present-day knowledge of the relation between the color and the intensity of the light given out by hot bodies, we can perform it by calculation with a reasonable degree of reliability. From this standpoint it becomes evident at once that the greatest apparent diameters must belong to those stars which are at the same time *bright* and *red*. Among all the stars of the sky, these are preeminent for the combination of these characteristics: Antares in Scorpio, Aldebaran in Taurus, and Betelgeuse in Orion, or Alpha Orionis as it is often called.

Estimates made on the best available data by Eddington in England and the present writer in this country showed the apparent angular diameters of these stars were probably as great as two or three hundredths of a second of air, and hence should be within the measuring power of the new 20-foot interferometer.

The instrument, constructed last summer, was put into use at Mount Wilson this winter, and proved at once to be successful. When turned on Alpha Orionis, the fringes, which were clear when the mirrors were set six feet apart, became fainter for a separation of 8 feet and vanished when the distance of the mirrors was increased to 10 feet. White stars, like Procyon still gave conspicuous fringes at this setting, showing that there was nothing wrong with the instrument. There can be no doubt, therefore, that the diameter of the star has actually been measured. A preliminary calculation makes it 0″.045—rather larger than the values theoretically predicted, but still very small, as we ordinarily reckon things. A one-inch ball, seventy miles away, would look large enough to eclipse the star completely (provided that the principles of geometrical optics could be applied to so extreme a case).

There is no doubt that the diameters of some other bright red stars can be measured, and soon will be, with the same instrument. The white stars, however, even the incomparable Sirius, are in all probability beyond its power, though still more puissant instruments capable of measuring them, may yet be constructed.

Small as the apparent size of Betelgeuse, regarded as a speck in the sky, may be, its real meaning is amazing. This star is far from being one of the near neighbors; indeed it is so far off that its distance is almost too great to measure. Observations made at Yale years ago gave a parallax of 0″.030.

Unpublished photographic measures at Allegheny, and spectroscopic observations at Mount Wilson, indicate a still smaller value. He would be a bold man, at the moment, who would venture to set a value for the parallax which he would guarantee to be less than fifty per cent in error; but all the determinations agree in one respect; they indicate *that the star's parallax is less than the value now found for its diameter*, which, in other words, means that *the diameter of the star is certainly greater than the distance which separates the earth and the sun* and probably much more than a hundred million miles.

With the best data available at present, it seems probable that the parallax is about 0″.015 and the diameter some 300 million miles greater than that of the earth's orbit. The added interest which this gives to the star will probably lead to additional observations for parallax, so that in a few years our knowledge will be much more precise than it is now.

Meanwhile, it is of deeper interest to realize that another milestone has been passed in the long road of our study of the universe. The stars, which from the days of the Chaldeans till now have seemed as mere points of light—specks in the sky—have at last yielded to direct observation the secret of their real magnitudes. They are no longer specks, but disks, and in a few years more we may be able to write long lists of their actual dimensions.

CLOUDS AND THEIR SIGNIFICANCE

WHEN closely observed, clouds are remarkable indices of atmospheric processes and movements. Their forms and motions may be used not only directly in determining what general winds and turbulence exist at different levels, but also in surmising the vertical distribution of temperature and humidity. Here, without the expense of apparatus, are the means for discerning what is happening in the atmosphere up to great heights, and, therefore, the means for determining the causes of certain features of our weather, and for forecasting local changes. Also, the effect of cloudiness on the temperature and humidity of the lower air is not to be overlooked.

The cloud transformations and movements during the passage of a strong low-pressure area in winter gives a fairly clear picture of the internal dynamics of such a storm. As the low approaches, a relatively warm southerly wind enters like a sideways-moving wedge over the cold surface air, and under the westerly upper wind. The lower surface of contact is frequently marked by stratus clouds formed by mixture, and the upper by alto-cumulus clouds formed by thermal convection due to the warmth of the southerly wind relative to that above. Later, the warm wind reaches the earth's surface. The lines of appreciable wind convergence are marked by nimbus and more or less continuous rainfall. Where such nimbus is formed the forced ascent of the air may go to great heights and thus supply the fast upper winds with the material for the drawn-out cirrus and cirro-stratus clouds that go far in advance of the storm and later for the heavy alto-stratus. As the center of lowest pressure goes by, perhaps not far to the north, an underrunning wedge of cold air may, by raising the warm moist southwesterly current above, bring on a few more hours of rainfall. This cold wind carries strato-cumulus clouds, formed by the turbulence and thermal convection, for perhaps a day, while the last of the long SW.-NE. lines of alto-stratus and cirro-stratus clouds, forming by the underthrust of the lower wind which lifts the higher moist layers, gradually pass over the eastern horizon.

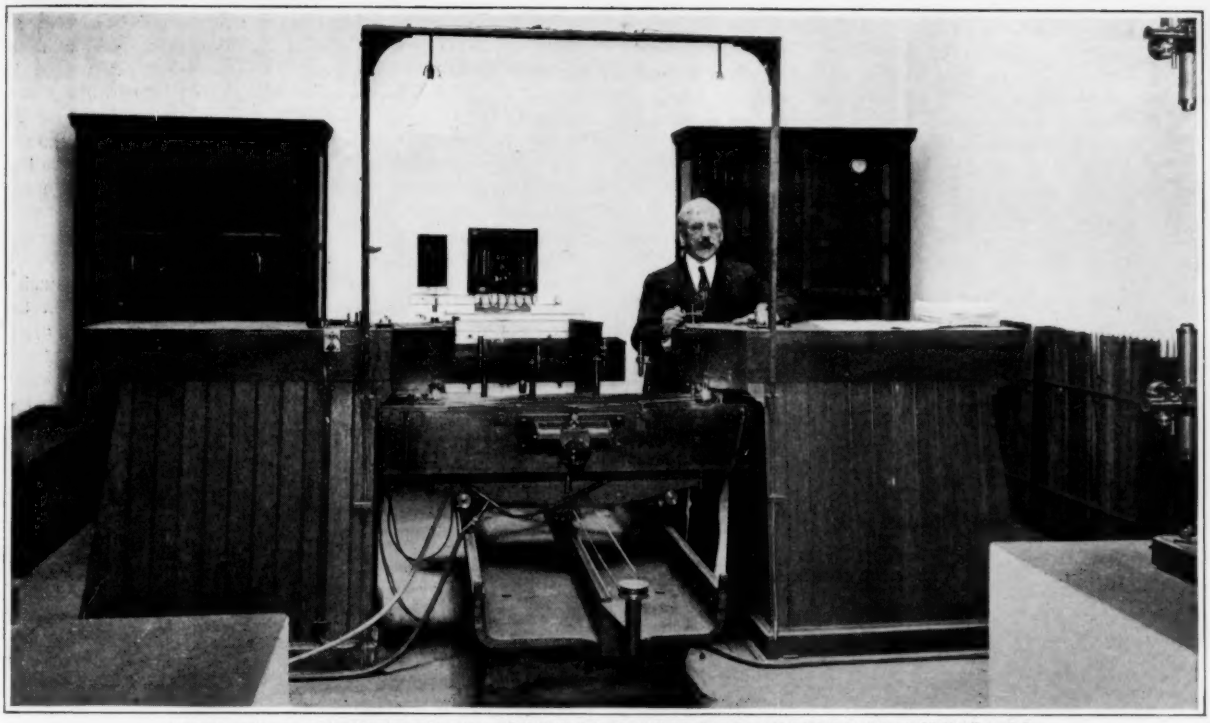
It is evident from studies of the appearance and transformations of cloud forms that the different types of clouds are very closely interrelated and pass from one form to another without any recognizable dividing line.

Since our weather is largely the result of the interaction of over- and under-running winds, clouds as indices of such are valuable in showing what is going on and what is to be expected. Cloud observations are finely complementary to pilot-balloon observations, for which there must be clear air and a lack of even intermittently intervening clouds. The whole domain of meteorology has no easier, more interesting, or more promising aspect for observations and study than clouds.—Abstract of a paper read before the Washington Academy of Sciences by Prof. C. F. Brooks.

EXTRACTION OF FIFTH ROOTS BY THE SLIDE RULE

IN view of the fact that formulæ containing 5th roots occur in hydraulic and other work, Messrs. Ginet and Gerard give a method of finding them on the ordinary slide rule.

The number, *A*, of which the 5th root is to be found, is read on the top scale of the rule, and the slider is adjusted by trial and error until the required root is read on the bottom scale of the rule against the *I* on the slide and at the same time on the upper scale of the slide against a number, *B*, on the upper scale of the rule, which is itself also seen on the upper scale of the slide opposite *A* on the upper scale of the rule. Care has to be taken that the correct halves of the upper scales are used according to the number of figures in the number before the decimal point.—Abstracted through *The Technical Review* from *Produire*, Aug. 10, 1920.



DIRECTOR GUILLAUME TESTING STANDARD METERS WITH THE BRUNNER COMPARATOR

The International Bureau of Weights and Measures

An Interview with Charles Edouard Guillaume, Winner of the Nobel Prize for Physics

By Jacques Boyer

M. CHARLES EDOUARD GUILLAUME, director of the International Bureau of Weights and Measures and 1920 winner of the Nobel Prize for Physics, was kind enough to grant an interview at his office in the aforesaid International Bureau, where he has done the greater part of his remarkable research work, and which he has been at the head of since the retirement of his predecessor, M. René Benoit, in 1915.

My kind host did the honors of this building, a veritable palace of precision, as it might be termed, which is located at St. Cloud and tenanted by a technical staff which is small in numbers, but choice in quality, as the members must needs be to handle the delicate instruments in their charge. It is impossible to try to describe in this brief article the minute precautions for the securing of accuracy, which are in force in these laboratories of the science of metrology or measurement. I will merely state in passing that all of these apparatus rest on piers of masonry having their foundations firmly rooted in the earth itself. Openings have been made in the floors of the various rooms to permit the entrance of these massive structures, so that the physicists making use of them can rely upon their solidity to prevent any outside influence from affecting their delicate balances and comparing rules.

"To begin with," said M. Guillaume, "kindly contradict the vexatiously erroneous opinion, held not only by *hoi polloi* but even by many of the learned with respect to the achievements of the metrologist. It is true enough that he is commonly conceded to have trained hands and eyes, to be a faithful observer, and to possess the inexhaustible perseverance required to make calculations involving the 10-millionth part of a millimeter, but it is too frequent a mistake to deny him the possession of creative imagination. Why, it was only the other day that some dull and tedious occupant of a professor's chair solemnly remarked that the metrologist must be compared to the plow-horse patiently digging his furrow while the man of new and original ideas is the race-horse swiftly covering space to the plaudits of an admiring crowd!

"However," continued M. Guillaume, "the metaphor is not entirely displeasing to me—for when once the race is over what is there to show for it but a little dust and a little noise, while in the furrow traced by the steady plow-horse the coming harvest will tomorrow lift its head. Is it not a patent fact, indeed, that the great discoveries of science bear a close relation to the methodical labors of the metrologist?"

And as he warmed to his theme by degrees, the eyes of the famous metrologist flashed behind his glasses, and he continued to plead with zeal for recognition of the value of the work done by the members of his craft, proving that it is their labors alone which have rendered possible the greatest advances made in physics and in astronomy since the seventeenth century.

"Did not Galileo establish the laws which govern the inclined plane by measuring the time required for a body to descend the said plane, and prove the isochronism of the oscillations of a pendulum by comparing during the course of some religious ceremony, the beats of his own pulse with the duration of the oscillation of a chandelier suspended from the vaulted roof of the Cathedral of Pisa?

"Would Newton have been able to discover the law of the universal attraction of matter but for the previous measurement of the arc of a meridian made by the French astronomer Picard at the command of Louis XIV? Was it not, thanks to the precision of their balances, that Lavoisier, Proust and Dalton were able to throw fresh light into the labyrinthine mazes of alchemy and thus transform a mass of obscure recipes and bizarre experiments into a true science—that of

chemistry? Do we not owe our knowledge of the law of the conservation of energy to the brilliant calorific measurements made by Joule and by Regnault, and that of radioactivity to no less sagacious measurements made by Becquerel and by Curie in those still more mysterious realms of research—the world of atoms and the constitution of matter?

"Furthermore, in the science of physics the constant relation between cause and effect becomes evident with certainty only from experiments in which effects are known whose various causes have been measured—more especially the weightier of these causes when the others play an obscure rôle."

THE INSTRUMENTS

But let us turn aside from these philosophic and theoretical ideas uttered by our learned guide in order to examine the remarkable instruments which, protected from the vibrations of the ground in the City of Light, enable the learned metrologists who employ them, to achieve from time to time a new decimal in their calculations of extreme precision.

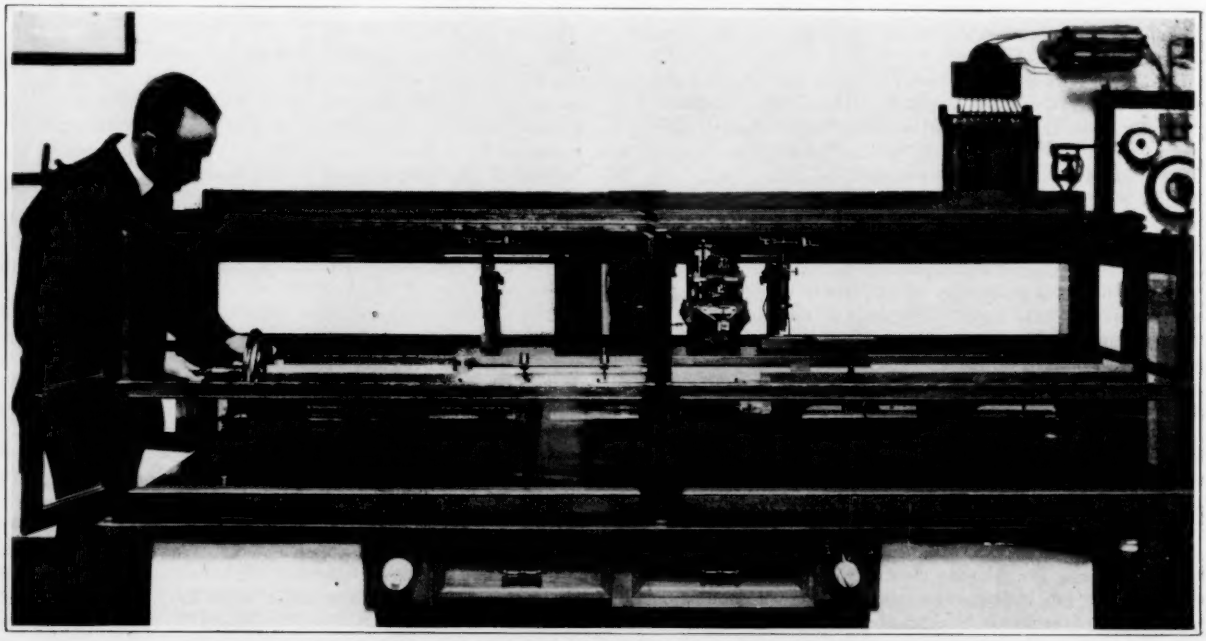
Such a conquest implies, it must be borne in mind, a very large number of improvements in matters of detail whence there will spring tomorrow some fresh discovery.

Comparators.—For the comparison of standards of linear measure, instruments known as comparators are employed. The International Bureau of Sèvres possesses several types of these. Essentially they consist of two piers bearing two microscopes a meter apart provided with micrometers, beneath which are brought, by means of special mechanisms, the two meter bars which it is desired to compare.

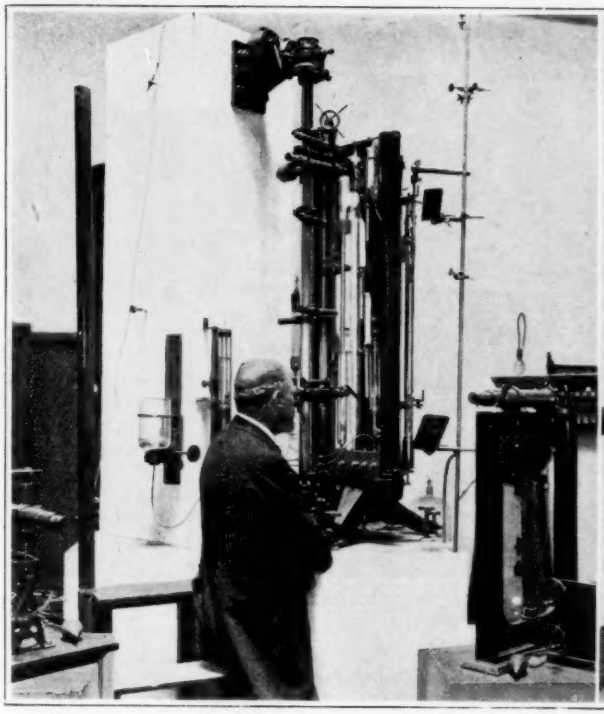
Comparators differ in details of construction according to the purpose for which they are intended. The first one built, which was the work of the Brunner Brothers, made measurements of the line type, *i.e.*, the length is measured not between the two ends of the bar but between two lines engraved in the vicinity of either end. The microscopes firmly attached to strong piers of masonry carry micrometers similar to those adapted to optical instruments. The linear divisions of the comparator correspond with the pitch of the micrometer screw thread so that the angle through which the barrel is rotated gives a measure of the displacement of the hair line of the microscope. The bed of the comparator itself consists of an enormous structure of cast iron. A very heavy carriage is rolled along a track formed by the upper edges of this bed by means of a hand crank which controls a series of gears. Two tanks are mounted on the carriage and in them the two standards that are to be compared are placed in shaved ice, or else water is circulated in a water jacket surrounding the tanks so as to maintain a uniform temperature. Means are provided for moving the bars in either a longitudinal or a transverse direction. The observer then compares the two bars by adjusting the hair line of his microscopes to the fine lines traced on one bar and, then moving it out of the way, the second bar is brought into the field and the displacement of its lines is noted.

The second comparator is employed to study the expansion of meter bars. It differs mainly from the one above in the fact that the carriage supports two tanks, one meter apart from each other; a bar is placed in each tank and they can thus be brought to different temperatures. One of them, taken as a standard of comparison, is kept at a fixed temperature, while the other one is heated or cooled. It is thus possible to measure the elongation or the contraction by comparing the length of the rule after each experiment with that of the standard. We will not dwell on the difficulty experienced in keeping the temperature constant for a sufficient length of time. Thanks to certain devices the physicists working in the Bretenil Pavilion have succeeded in keeping a liquid bath for several hours at a temperature so constant as to vary only by a few hundredths of a degree. These two instruments make it possible to determine the difference in length of two meter bars within a few microns—*i.e.*, a few thousandths of a millimeter!

The Universal Comparator.—With this instrument, which differs considerably from those described above, the observer can make all sorts of comparisons, thanks to the fact that it has both a longitudinal and a transverse movement, and because of the mobility of its microscopes. These are no longer fixed, but are borne upon carriages rolling upon a sort of bridge placed in a horizontal position between two supports of solid masonry. A heavy iron casting terminating in steel ways upon its upper rim, furnishes an absolutely perfect horizontal surface on which the microscopes are moved. As soon as these have been brought to the required position for any given experiment, they are secured by a clamp. A heavy carriage travels beneath, and is provided with supports for the standards to be examined. Corrections can be made by various



MACHINE FOR MAKING ACCURATE GRADUATIONS ON STANDARD LINEAR MEASURES



MAKING AN OBSERVATION WITH THE STANDARD NORMAL BAROMETER AND MANOMETER

PLACING THE WEIGHTS IN THE BUNGE BALANCE WHICH MAKES WEIGHINGS IN VACUUM

complicated devices into whose details we can not here enter. Moreover, the instrument has been provided with a standard rule 2 meters long and divided into centimeters; with this also it is easy to compare end standards; to determine other lengths than those of the metric system; to establish standards of sub-multiples of the meter—especially of the millimeter—which is so necessary in order to determine the degree of precision which it is possible for the observers to attain with the micrometric instruments employed in these delicate experiments. The Hartmann comparator, for example, registers *automatically* the slightest differences of dimension which exist between the pieces placed in it. It consists of a steel bed upon which are two bases, one of which is fixed, while the other is capable of sliding along the bed. The first carries a micrometer screw whose head is surmounted by ten arms, each of which carries a pen similar to those found in registering-barometers. The point marked by the pen upon the recording drum, toward which it is attracted by an electro-magnet, indicates the length of the standard. With this instrument the difference in length between two pieces can be determined quickly and with considerable precision.

Finally, in order to verify the geodetic rules, which are four meters in length, a special instrument is employed which is formed by the association with each other of five comparators. In order to eliminate the slightest variations of temperature which might falsify the results obtained in the observation, the rules to be examined are placed in a closed container, filled by a continuous current of water kept at a fixed temperature. The manipulation of this geodetic comparator is done by electricity and is very complicated.

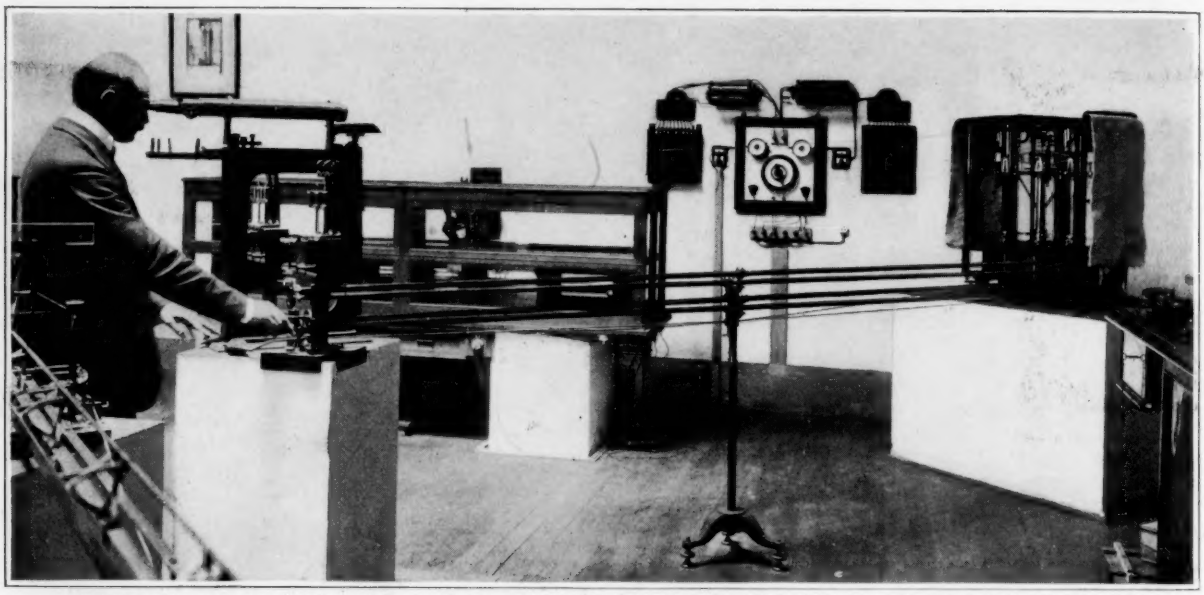
Precision Balances.—Let us pass on now to the second class of instruments found at the International Bureau of Weights and Measures. These are precision balances of great delicacy, nearly all of which are so constructed that they may be read at a distance. Insulated in glass cages supported on piers of masonry which do not touch the floor, they are employed to make comparisons of mass, especially of standard kilograms. One of them, made by Dr. Bunge, is even capable of determining weights in a vacuum. Let us enter the room which contains them in the company of Prof. Guillaume's assistant, M. Vollet, who has charge of this department, and listen to his explanation of the manner in which an experiment is performed.

The day before that fixed on for the experiment the observer places in the cage of the apparatus the weights needed for the next day's work; he then avoids approaching the balance lest thermic disturbances be produced by the heat from his body. Twenty-four hours later, by means of one of the long metal rods which are seen in one of our illustrations and which rest upon solid blocks of masonry, he performs the desired weighing operation at a distance of 4 meters. In other words, the ingenious mechanism at his disposal enables him to place the weights upon the pans, to release the latter, etc., without coming near the scales. He watches the oscillations of the beam of the balance by means of a small telescope. A mirror firmly attached to the balance beam reflects a graduated scale whose movements made when the beam oscillates are seen by the experimenter through the telescope. It is only necessary for him to note its extreme successive positions, then find the average, and the position of equilibrium can be deduced therefrom by means of a simple calculation.

We shall not dwell here upon the various devices invented by Rueprecht, Bunge and other makers of scientific instruments by means of which the physicists on the staff of the International Bureau can determine the difference between two kilogram weights to within about 1/100 of a milligram, while in other rooms temperatures are measured with a precision hitherto unknown.

Modern Geodesy.—"But now," said Prof. Guillaume, "we must go down into the cellar in order to comprehend the work done in connection with modern geodesy. As you doubtless know, it was I who, together with my predecessor, M. Benoit, suggested the use of wires made of *invar* to measure secondary bases."

But the modesty of my guide kept him from adding that it was he himself who had discovered the anomaly in the case of the nickel steels, those famous alloys known under the name of *invar* (an abbreviation for invariable). Let us briefly



COMPARING STANDARD KILOGRAMS FROM A DISTANCE SO THAT THE HEAT OF THE BODY WILL NOT AFFECT THE DELICATE INSTRUMENT

remind those of our readers who are rusty in their metallography that alloys having 25 per cent of nickel expand much more than would be indicated by the law of mixtures of metals, but that when the nickel is added by degrees the expansibility is observed to become rapidly lower, passing through a minimum, at about 36 per cent of the nickel, and then ascending until it reaches the degree of expansibility of nickel. Those alloys which approximate the minimum bear the generic name of invar, and their expansibility when they have been merely laminated while hot and then air cooled is only about one-tenth that of their constituents. Furthermore, Guillaume has shown that it is possible, by means of certain thermic and mechanical treatments, to reduce even this low degree of expansibility and to obtain *anti-expansible alloys*—*i.e.*, alloys which actually contract when heated. New thermic treatments offset the expansibility of these alloys, so that they can be brought if so desired to a state in which the expansion is *nil!*

By means of the theoretic data thus obtained the steel works of Imphy, of the Society of Commentry-Fourchambault, and the Decazeville have thus been able to obtain for geodetic measurements many kilometers of wire practically without capacity for expansion. The use of these wires in connection with the rapid method invented by the Swedish geodetic expert, Jaderin, has made it possible entirely to transform the measurement of bases by combining a light and easily handled material with wires of invar freely stretched between two definite bench marks. In this manner it has been possible to reduce the cost of measuring bases to 2 per cent of its former cost without sacrificing precision. The measurement of the Simplon is a classic example of this new mode of measurement. In order to subject these invar wires to a permanent control, M. Guillaume has constructed in the cellars of the International Bureau a reference base 24 m. long, consisting of a series of bench marks sealed into a thick wall. At the two extremities of the base are two pulleys mounted in ball bearings over which pass flexible cords attached to the wire and stretched by weights weighing 10 kg. each. Two observers are placed opposite these bench marks, which are strongly illuminated by the light from powerful projectors, and bringing toward each other the graduated rules in which the wires terminate, they make a series of simultaneous readings of their respective bench marks with respect to the graduation of the rules. In this manner the wire is compared at the base.

For the movable bench marks, whose distance apart upon the ground is determined, two by two, M. Benoit and M. Guillaume have invented a huge wooden tripod on top of which is a movable table. Upon this table is placed a small metal tripod kept in position by 3 springs, upon which rests a plate surmounted by a vertical pin whose micrometric movement is secured by the aid of 3 horizontal screws. The pin is pierced by a vertical hole through which passes a plumb line.

A base can be measured much more rapidly by means of this system than by the old methods and requires a smaller staff—only about 10 men. Finally the possible error does not exceed a millimeter.

Another of the most remarkable pieces of research to be found at the Bureau is the work which the learned American scientist, Michelson, has been pursuing here for the last 20 years. This skilled man of science has succeeded by processes into whose details it is impossible here to go, in comparing the fundamental base of the metric system with a natural unit, the length of the wave of the red light of cadmium. This unit is dependent only upon the properties of atoms and of the ether. It appears, therefore, in the words of its author, "one of the most fixed magnitudes throughout the whole realm of nature." His delicate experiments have given the following figures as the average value: 1 meter = 1,553,164 wave lengths of this radiation in the air at 150° C. and at a pressure of 76 cm. Thus it is possible today to declare that if all our standards should disappear in some vast cateclysm, it would nevertheless be possible to restore them by reversing Michelson's process since with the data of his treatise upon the subject all the units of the metric system could be found. The French astronomers of the 18th century were not in error as to the future of the meter when they gave it the proud device—*For all times and for all peoples.*

The present director of the International Bureau of Weights and Measures continues, therefore, the proud tradition of his famous forerunners and he has personally done much to spread the use of the metric system throughout the world, although our English and American allies still refuse to adopt it officially as a whole.

When my visit to the laboratories of the Breteuil Pavilion had been concluded, M. Guillaume led me once more into his office, whose windows give upon the valley of the Seine.

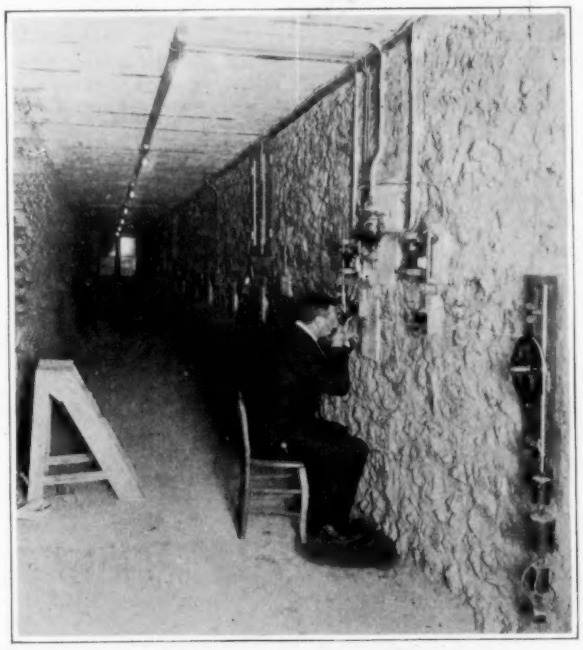
Here he entertained me by way of finale, with an account of his latest researches—in particular with the applications of nickel steel to the science of chronometry.

The combination of the brass in a balance wheel with an alloy containing 42 per cent of nickel has enabled us boldly to attack the problem of the secondary error of chronometers which had long exercised the ingenuity of horologists, but had been only partially solved at the expense of much complication of mechanism. Thanks to the use of the Guillaume balance, considerable advance has been made in the construction of chronometers of precision—and this progress is shown by the annual reports of the observatories, in particular those from Besançon.

The Spiral Compensator.—The *elasticity* of nickel steels furnishes as great an anomaly as does their expansibility. This was discovered in invar by Marc Thury and by Paul Perret simultaneously; it was first studied by the latter physicist in collaboration with M. Guillaume and led to the construction of the spiral compensator by whose use we are able to dispense with the use of the compensated balance, in ordinary watches at any rate.

M. Guillaume had always believed that this spiral might become an element in a provisory solution of the problem. However, up to the present time more than 50 million watches have been provided with spiral compensators, and this has enabled manufacturers to lower greatly the price of common watches.

As a result of his study of the ternary alloys, *i.e.*, those which contain a third element besides iron and nickel—particularly chromium or magnesium, M. Guillaume came to the



TESTING A WIRE FOR SURVEY WORK

conclusion that it would be possible to obtain an alloy having a constant elasticity and thus obtain a more perfect solution of the problem. It was only in last July (1920) that he announced the completing of the invention to the Academy of Sciences. This announcement occasioned a tremendous sensation among horologists, since it was instantly preceived that it implied a highly important change in the system of compensation in chronometers.

The New Alloy Elinvar.—This remarkable alloy has been termed by its inventor *elinvar*, an abbreviation of the words *elasticity invariable.*

I must not forget to add this article M. Guillaume's closing words to the effect that he had come to France 37 years ago expecting merely to work here for a few months and then return to his Fleurier, in Switzerland, his native land. "But the elegance, the lucidity, and the precision of French methods of research have seduced me to stay and have led me to achieve success," were his closing words.

PURIFYING STEEL INGOTS WITH ALLOYS OF TITANIUM

THE employment of titanium as an alloy for steel makes it possible to obtain steels having a very homogeneous composition without flaws, cracks, or inclusions of gas or foreign bodies—furthermore, it diminishes the effects of segregation. In the Revue Universelle des Mines (Liége) for April 15th, M. Bertrand furnishes the following interesting information concerning this rare metal:

The best known mineral containing titanium is rutile or titanium oxide, TiO_2 which is found in igneous and metamorphic rocks. This mineral contains from 98 to 99 per cent of TiO_2, the remainder consisting of oxide of iron. There are several crystalographic varieties: Brookite, anatase, and octahedrite. The principal deposit is found in Norway, but it also occurs in Virginia, in Dahomey, on the Gold Coast, on the banks of the Niger.

The most widespread mineral of titanium is ilmenite $FeTiO_3$ which contains a maximum of 52 per cent of titanic acid. Abundant deposits of this mineral are found near the coast in Canada, in the Senegal, and in New Zealand; these proceed from the disintegration of shallow marine deposits.

Thus far no use has been found for the pure metal; it is employed only in the form of alloys which are both more fusible and more readily obtained, principally in the state of ferro-titanium, and ferro-carbo-titanium, but sometimes as cupro-titanium and as mangano-titanium.

Ferro-titanium is produced by the German process, known as the Goldschmidt process (alluminothermy), by which the reduction of the mineral is secured by means of powdered aluminum; this has the serious disadvantage of being very costly because of the large quantity of aluminum required. Ferro-carbo-titanium is prepared by the Rossi process in the electric furnace in which a mixture of the mineral with charcoal is reduced. The following table gives comparative analyses of these two alloys:

Elements	Ferro-titanium	Ferro-carbo-titanium
Ti	25.00	15.79
Fe (per difference)	68.19	74.30
C	0.00	7.46
Si	1.25	1.41
Al	5.50	0.80
Mn	0.00	0.11
S	0.01	0.08
P	0.05	0.05
	100.00	100.00

Steels are more and more employed at the practical maximum of their resistance, which necessitates as high a degree of purity as possible. For this reason great effort has been made during recent years to avoid flaws and cracks, to remove foreign bodies and gases and to annul, so far as possible, the effects of segregation. This has been accomplished in part by projecting aluminum into the pocket of the mold at the moment when it receives the molten metal. However, it is necessary, in this case, to sacrifice the upper portion of each ingot where the metal presents a network of flaws and of slag, and where the cooling produces a more or less deep retraction pocket. A more serious matter consists of the fact that the aluminum produced from alumina does not fuse until it reaches a temperature of 2,050° C., whereas the fused metal has a temperature of about 1,600° C.; hence the alumina remains in a solid state in the bath and forms a lump in the steel.

PHOTOGRAPH OF THE NEW CONE OF MOUNT VESUVIUS TAKEN FROM THE FLOOR OF THE OLD CRATER. THE CONE IS IMMEDIATELY ABOVE THE OLD VOLCANIC CONDUIT

LAVA OVERFLOWING FROM THE NEW CONE AND MELTING ITS WAY INTO HARD LAVA PREVIOUSLY SOLIDIFIED

Volcanic Architecture

How Vesuvius Rebuilds Its Broken Cone

By Frank A. Perret, Volcanologist

Illustrated with Photographs by the Author

READERS of the SCIENTIFIC AMERICAN MONTHLY will no doubt recall the great eruption of Vesuvius in the spring of 1906. Before that event, the cone of the volcano had been built up to an elevation never before attained, with a pointed summit and a small crater. The eruption cored out, undermined and blew away the entire top of the mountain, leaving a great crater half a mile across and a thousand feet in depth, and producing a profound change of form.

Then followed seven years of external repose during which time not so much as a thread of smoke could make its way through the plug of débris which clogged the conduit of the great volcano. But the lava was silently eating its way upward, and early in July, 1913, a vent was formed at the bottom of the abyss, with the familiar glow of former times. From this opening there gradually welled up the new supply of lava which has been filling the great cavity and building up the base of what will constitute the new and greater cone. The embryo of this cone (formed of the lava welling up and thrown out from the vent) already exists, and may be seen in one of the accompanying photographs rising above the level of the crater floor.

The author of this article, Frank A Perret, volcanologist of the Smithsonian Institution, is well known as a most daring investigator in this extremely hazardous field of scientific research. He became honorary assistant to Professor Matteucci of the Royal Observatory at Mt. Vesuvius in 1904 and made a special study of the great eruption of 1906. He also studied the eruptions of Stromboli in 1907, 12 and 15, and Messina in 1908. For his valuable services which resulted in the saving of thousands of lives he was knighted by the King of Italy. Having witnessed the demolition of the great cone of Vesuvius fourteen years ago, he is naturally much interested in watching the gradual construction of a new cone in the floor of the old crater.—EDITOR.

Now, when I speak of the crater floor, people protest. They object to the crater having a floor. They think of it as an opening leading down to the realms of Pluto, so how can it have a bottom? And yet the matter is very simple. "Crater" means cup, and it is generally more like a basin; and a basin has a bottom, even though there may be an opening in it—the point is that the opening is smaller than the bottom of the basin, and not only so, but the opening—when the volcano is active—is full of a heavy liquid rock, so there is no real cavity. Furthermore, as the liquid is generally rising, it accumulates around the vent and builds up a

mound—a cone—to a considerable height above the crater floor. And so the floor level is always rising, not by being pushed up from below, but by the superposing of material which overflows from the pipe, so that when we spend a night on the crater bottom, our camp of the year before lies buried some hundred feet below, and the changed conditions require also a horizontally different site, in order to find a happy medium between the extremes of heat and cold.

Here, again, people protest. They object to my feeling cold at the bottom of a fiery crater, where one can read all night by the bright glare of incandescent lava. They cannot possibly object to it more than I do, but the fact remains that it is cold at night, even in August, and the explanation is, here also, a very simple one. For, although the crater may be—and was—a thousand feet deep, it is at the top of a mountain four thousand feet high, so that a person at the bottom of the crater—instead of being nearer to the center of the earth than the average mortal—is three thousand feet above sea level, and at that height the air is cold at night, even though there may be red hot lava fifty feet away. The difficulty is, as I have said above, to find a happy medium.

If the present average rate of activity continues, we shall see from Naples, in a very few years, the little cone peeping above the rim of the great crater, and from that moment Vesuvius will begin its transformation of shape until once more the great cone of the mountain will be regular, terminating in the pointed summit made familiar by postcards without number. But from the present time—and for ten years to come—this volcano will constitute one of the most imposing spectacles on earth—a great crater, upon the edge of which one stands in perfect safety, and looks across at an actively erupting cone whose ejections are filling the basin and building the new mountain from which—still later—will burst forth another great eruption to complete the cycle.

DESCENDING THE OLD CRATER WALL

The wall is 350 feet deep having been filled in with lava from a depth of 1,000 feet since the great eruption of 1906.

THE CELESTIAL SPEED RECORD

SPECTROSCOPIC observations of the nebula Dreyer No. 584, in the constellation of Cetus, show that it is receding from us at the frightful velocity of nearly 2,000 kilometers (1,240 miles) per second. The observations were made by Dr. V. M. Slipher of the Lowell Observatory. This beats the previous celestial speed record by about 800 kilometers. Most objects move through the heavens at less than 100 kilometers per second. The earth jogs around the sun at the leisurely pace of 30 kilometers per second, 30 times the speed of a bullet.

MEASURING THE TEMPERATURE OF THE LAVA FLOWING FROM THE NEW CONE, WITH AN ELECTRICAL PYROMETER

The temperature registers 1,850 degrees Fahrenheit and the assistant is obliged to avert his face from the blistering radiant heat

The Place of Life in Nature*

How Is It Related to the Cosmos, the Greater Part of Which Is Non-Living?

By Ralph S. Lillie

IT is a peculiarity of our status as self-conscious beings, whose existence and activities are bound up with the special form of material organization called vital, that life appears to us as the central and all-important fact of nature. The qualities of living beings are always present to our attention. In most of us the feelings of activity, energy and spontaneity are strongest when organic life is strongest—when we are most "alive"; the popular meaning of the word *vitality* comes from this fact; and the naïve tendency has always been to ascribe a special freedom or originative capacity to life, and to regard the non-living part of nature as something radically different from the living, as something inferior—or basely mechanical. But obviously this view, as the product of prepossession rather than reasoning, can have no scientific or evidential value in relation to the problem of the place of life in nature. Most of us can remember wondering as children at the absurd self-importance of inferior animals like house-flies; later on we find that this curious self-regarding attitude of living beings is simply one of their general or "class" characteristics, shown even by plants. It would appear therefore that when man—who is certainly not the least egotistic of the animals—assigns to life a position of central importance in the cosmos, he may be merely furnishing another example of this natural propensity, which has its biological origin in the inherently self-conserving or self-protecting tendency common to all organisms. This property is a necessary condition of organic survival; it is an example of what is called an "organic regulation" and even has its analogies in various automatically regulated mechanical devices. We must face the possibility that in reality life has no unique or privileged position in nature, but is merely one out of the many purely casual and inessential results of the operation of blind natural forces. At least a biocentric conception of the cosmos must justify itself on other grounds than those of the instinctive human prejudice.

I propose this evening to discuss the question of how life is related to the rest of nature, the greater part of which is non-living in the usual understanding of the term. How is this peculiar and special development which we describe as *living* to be derived from a cosmos which close observation shows to be subject everywhere to rigid determination by mechanical and mathematical laws?

What, then, is the essential relation of life to the cosmos? In earlier times mankind regarded the world and its inhabitants as something emanating from life, as created and sustained by the volition of a living deity or deities, and as subject to more or less arbitrary divine—or sometimes diabolical—intervention; life was the primal cause or originating condition of things; the deity breathed into his creations the breath of life; by this action something not previously present was added to nature; in a word, the source of life was "supernatural." How far we have traveled from this naïve belief in these scientific days I need scarcely remind you. To most of us, especially biologists, life is not a primitive but a comparatively recent and derived phenomenon, one product of the evolution of a cosmos which at first was entirely non-living; in the temporal or historical progress of nature complex or "heterogeneous" systems, including finally life, by degrees emerged from the originally indefinite or homogeneous primordium (to paraphrase Spencer); life as thus conceived is not a primary agency, but a secondary and somewhat exceptional derivative of the natural process. This view seems now firmly based on naturalistic observation; and in fact it is usually regarded as a summarized objective description of what has happened during the past several million centuries.

The question of whether or not to accord primacy to life is perhaps not one to be settled by observation alone. When we view cosmic events in their historical succession it seems certain that life is a later rather than an earlier appearance in nature; there is no doubt that the physical conditions on the globe were incompatible with the existence of living matter until a comparatively late stage of planetary evolution. But the argument from the geological succession of life on the earth is an equivocal one and not decisive, since its opponents may well reply that the very appearance of life at a certain stage implied its previous latency; how otherwise in a mechanistically controlled world could it ever have come into existence? The character of the dilemma is evident; in any physico-chemical view of natural evolution the casual chains extend back indefinitely and uninterruptedly; whatever appeared at any time or place in the sequence was in this sense predetermined—had a series of mechanistically interconnected events leading up to it. The reference to preëxisting causes thus stretches back *ad infinitum*, and whatever existed at any time, however remote, must be referred for its ultimate causal determination to what we can only call, however vaguely, the original constitution of nature. Yet it would seem that we cannot assign a physical but only a metaphysical meaning to this phrase. Claude Bernard recognizes this dilemma and comments upon it, but without concerning himself greatly, since he was satisfied that for the solution of concrete scientific problems (in which he was mainly interested) only physico-chemical or experimental methods have any real value. Apparently it is now agreed among philosophers that casuality, while a constant feature of natural existence, as it presents itself to our senses, is not a factor to be appealed to in accounting for ultimate origins.

Defining the situation in this manner enables us to formulate the alternatives of the problem somewhat more clearly. We may put the matter thus: Is life a development from physical nature, peculiar only in expressing or exemplifying in an intensified or centralized form certain fundamental features or tendencies of natural processes? Or is it a special agency or activity set apart from non-living nature, having peculiarities which are sharply contrasted to the inorganic and not derivable from it? These would seem to correspond to the alternatives of a natural *or* a supernatural mode of origin. If life is a product of natural evolution, is it an expression of a deeply rooted or essential property or characteristic of nature? or is it a casual product, one of the many purely mechanical effects of what used to be described—in a phrase vaguely irritating to many persons—as a fortuitous concourse of atoms? It is to be noted that the former alternative recognizes a certain preëxisting trend or directive tendency reaching eventually its expression in living organisms; and it therefore seems more consonant with a vitalistic interpretation; the underlying "urge" or originative impulse which is postulated might be designated by Bergson's term, *élan vital*. The other is the mechanistic alternative, which regards the peculiarities that seem to set life apart from other natural processes as simply the result of the physical and chemical properties of the special material complex called *protoplasm*, especially its properties of constructive metabolism and growth, which are dependent on certain special and primarily accidental features of its physico-chemical constitution.

Let us now consider life as a fact of external nature and inquire what are the objective criteria of living as distinguished from non-living matter. First we observe that living

*Paper read at a meeting of the Royce Club, Harvard University, April 11, 1920. Reprinted from *The Journal of Philosophy, Psychology and Scientific Methods*, Vol. XVII, No. 18, August 26, 1920.

matter is not found diffusely distributed, but always as forming a part of some special organism. Many individuals of each species, similar in their activities and structure, are found, each in its appropriate habitat. The existing species of animals and plants are as a rule true to type and readily distinguishable from other species; individuals of the same species are closely alike, although somewhat variable. Thus the repetitive tendency, universal in non-living nature, exhibits itself also in living organisms; but living species are on the whole more clearly defined and exhibit fewer intergradations than non-living species, *e. g.*, of minerals; a highly specialized and individualized character seems to belong to the forms of living matter. But all of these forms have in common certain highly definite class properties, not ordinarily met with in non-living matter; and it is first necessary to state these as clearly as possible.

Living matter is sharply distinguished from dead matter by various remarkable peculiarities of activity or behavior, and by a unique physico-chemical and structural composition. The most striking feature of its activity is its power of growth or self-multiplication; this is shown by all of its forms, from the lowest plants to the highest animals. With the property of growth is to be included that of reproduction, which has been defined as discontinuous growth; *e. g.*, a cutting from a plant will grow into the complete organism under appropriate conditions; so also will a seed, which is equally to be regarded as a detached portion of the parent organism; and similar conditions are found in animals (regeneration, sexual and asexual reproduction), although here the extraordinary complexity of the process by which a fertilized egg develops into the adult seems to give the reproductive process a special status of its own. Even in this case, however, the essential nature of reproduction as orderly and specific growth toward a definite final organization is clear enough. All living material, then, is *growing* material—at least in certain stages of its existence, for there are natural limits to the increase in size of the individual in higher plants and animals—in other words, it is *synthesizing* material; and this brings us to what is apparently the essential feature of living organisms, considered as physico-chemical systems. All living matter is more or less continually engaged in transforming unorganized materials and energy taken from the surroundings into organized living material of its own kind. It thus tends automatically to add to itself; what is appropriated from the surrounding non-living world is actively transformed into its own organized and active living substance. This transformation is *specific; i.e.*, a special type of living matter or protoplasm, with a chemical composition, structure and activity identical with those of the original protoplasm, is formed. Each portion of protoplasm thus serves as a center of construction of similar forms. This condition has certain analogies to "germ-action" in inorganic processes, such as crystallization, but on the whole is a unique and distinctive property of living organisms. This property depends on certain highly definite processes of chemical transformation which have their special or individual characteristics for each species of protoplasm. If we put two different species of yeast or bacteria into the same culture-medium, each builds up protoplasm of its own kind; *i.e.*, each effects a special predetermined kind of chemical transformation in the materials which it incorporates from the surroundings. Each has the same external materials as its source of supply, but each transforms them in its own specific way, and hence builds up a special kind of protoplasmic structure which, having a special physico-chemical constitution or organization, exhibits corresponding special activities. The term *specificity* denotes this peculiarity. We thus conceive of each cell or each portion of protoplasm as primarily a center of specific chemical transformation or synthesis. Its other specific properties follow from this, including its power of maintaining these characteristics intact and transmitting them to other portions of living matter arising from it in growth or reproduction. "Heredity" is the name usually applied to this latter process; but it is important to note that the power of reproducing or replacing itself is one which is at all times active in living protoplasm. The living substance is continually being chemically decomposed or broken down by its own energy-yielding processes (usually oxidations of some kind), and unless there is a compensatory process of construction or replacement it sooner or later ceases to exist as living. The processes of specific construction must therefore balance or exceed this destruction if life is to continue; excess of construction implies growth, or increase in the quantity of living organized protoplasm; and reproduction is an aspect of growth, as already pointed out. In this sense "heredity" is always being manifested in living organisms; as Haldane puts it, "heredity is for biology an axiom and not a problem," *i.e.*, when dealing with living matter biologists assume or take for granted its specific transformative and synthetic power, just as chemists take for granted chemical affinity. The physiological units of the speculative biologists (gemmules, pangens, ids) have always been endowed by their creators with the property of automatic self-perpetuation and reproduction; and just at present this property is assumed without further question to be possessed by the chromosomes, which most geneticists regard as the bearers of hereditary qualities in higher organisms. But in the physiological sense no such theories of heredity can be regarded as ultimate; if chromosomes (*e.g.*,) determine the appearance of certain special characters in organisms (as now appears almost certainly to be the case), what determines the appearance of the special qualities possessed by a given set of chromosomes themselves? Surely not a second set of chromosomes—*i.e.*, similar physiological units of a lower order? Evidently these would require a third set of determinants, and so on *ad infinitum*, like the fleas in Swift's epigram. But the facts of physical science forbid any such *regressus*, since limits to divisibility are set by the atomic or electronic constitution of matter. The self-multiplying property of living matter is in reality an expression or consequence of the specific constructive side of its metabolic processes, and the problem of heredity resolves itself ultimately into the problem of the physico-chemical conditions determining this peculiar synthetic power.

Specific chemical transformation is the form of physical activity which is essential to living matter. There is an interesting general significance in this fact, for the most striking feature of chemical reactions, as distinguished from other natural processes, is that through their means substances are formed having properties entirely different from those of the original interacting substances. There is always the generation of novelty, the appearance of qualities and modes of behavior not deducible (at least at present) from those of the parent bodies; and it is this peculiarity which has enabled the life-process to create out of carbon compounds, salts, and water such a multitude of novel and varied forms. The synthesis of special chemical compounds in metabolism, in special structural and other relationships, thus makes possible the appearance of the qualities which we call vital. All living beings are primarily products of metabolism, in this general sense; they are formed, maintained, and perpetuated by processes of chemical transformation. They represent, in the purely physico-chemical sense, special collocations of matter and energy; and yet their synthesis in the manner broadly indicated necessarily involves the synthesis or creation of many other properties and modes of action which are of a different and higher order and give rise to the special conception of *vital*. The chemical process is the foundational one, but it brings into being systems having qualities whose existence could never have been predicted from a consideration of the chemical processes alone. These "vital" qualities have properties of their own requiring special modes of consideration and investigation. The organism is undeniably a physico-chemical system, but it is something else in addition. We come now to a consideration of the more specifically vital properties.

How can such complex systems as living organisms maintain themselves or even continue to increase and multiply in a nature which seems on the whole unfavorable to the preservation of special configurations of a complex type? Part of the answer has already been indicated. An organism maintains itself because its dissolution is normally balanced by an accompanying reconstruction; its materials and energy are replaced as rapidly as they are lost or destroyed, and hence the dependent vital characters, however complex they may be, are enabled to persist. In this general respect living organisms resemble certain other natural systems whose permanence also depends on the maintenance of a balance between integrative and dissipative processes of various kinds; a candle flame, a whirlpool, and fireworks such as the "devil's fountain" are instances; their persistence and individuality are due to an automatically controlled balance of diverse activities. The general class of physical conditions called *equilibria* enters here. Experience shows that two equal and oppositely directed forces or tensions produce where they come into contact a stationary condition, permanent unless disturbed; static equilibria, as in a balance or a stretched spring, are of this kind. Hence such equilibria can be represented by mathematical equations—a certain quality being recognized in the conditions determining the permanent state in question. The class of equilibria represented by organisms is of a more complex kind; they represent equilibria of processes, often called "dynamic equilibria." Any number of separate processes or activities, whose effects, taken singly, are of the most varied and frequently opposed kind, may be so coördinated that the total or resultant system preserves a constant recognizable character or unity. The component activities may be collected into two groups, which may also conceivably be symbolized by the expressions on opposite sides of an equation, the constructive or integrative processes of the one side balancing the destructive on the other. Each group, taken collectively or additively is equal and opposite to the other in its total or resultant effects; hence the two compensate each other and produce a stationary total condition. Thus when constructive and destructive metabolism in a living organism are equal there is balanced maintenance, indicated, *e. g.*, by nitrogenous equilibrium; when the one or the other exceeds there is either growth or regression. In all organisms the conditions making for dissolution are various. Take the case of a simple marine plant or unicellular animal as an illustration: the mechanical and chemical action of the environment, the tendency of protoplasmic materials to diffuse into the surrounding seawater, and especially the continued oxidation of protoplasmic constituents and loss of carbon as CO_2, all combine to diminish the living substance; this loss is replaced during life by the intake and transformation of food materials. When, however, the synthetic processes cease, as at death, the destructive processes are unbalanced and the organism is quickly disintegrated. On the other hand, with an abundant food supply and otherwise favorable conditions the synthetic process may predominate and lead to indefinite growth and reproduction.

Now this conception is applicable to all forms of life and also to life in its totality; its persistence implies that disintegrations are balanced or overbalanced by integrations. In the extraordinary diversity of organisms we find an infinity of different means by which this vital balance is maintained. When it is not maintained, as repeatedly happens in nature, a species becomes extinct. Living and stable species are therefore found to be organized in such a way that their persistence and perpetuation are ensured by all kinds of structural, chemical and behavioristic peculiarities and devices. These are usually called "adaptations," especially in those cases when some special feature of the environment is provided against: thus low temperature in the surroundings is countered in mammals by special thickness of fur; scarcity of food is compensated for by the special development of senses, intelligence and activity, as in most carnivorous species; enemies are thwarted by protective structures and modes of behavior. To particularize is unnecessary, since we are now interested in the general rather than the special character of living beings. In all such cases the adaptation represents a condition which favors the persistence of the vital equilibrium—something which enables the individual or the species to survive, especially the species, since cases are numerous where individuals are sacrificed to secure the survival of the species.

In general what we mean by an "adaptive" feature in an organism is some special peculiarity of structural organization or activity that directly aids in preserving the organic equilibrium, *i.e.*, in securing survival. A few concrete examples of internal and external adaptations will illustrate. The arrangement of the valves in the heart is adaptive, since it ensures the constant flow of blood in one direction and hence the constant supply of food and oxygen needed to maintain the cells composing the organism. The camera structure of the eye is adaptive in enabling the animal to react effectively to the stimulus of light waves reaching it from different directions of space—these light waves being indicators of the presence and situation of physical objects which are thus discriminated. A countless number of special adaptive structures and habits have reference to the special features of the animal's environment: arboreal creatures have special clinging devices; parasites are curiously protected; predatory animals are usually swifter, more powerful and more intelligent than their prey; the special instincts of an animal are its congenital adaptive modes of behavior. In brief, unless a character in some way definitely furthers continued existence in an environment it is not classed as an adaptation; its criterion as adaptation is that it favors the persistence of the species. To put the matter concisely, adaptation is a form of equilibration. This characterization expresses of course only the most general significance of adaptive characters and neglects the infinitely various details.

Physiological science is not yet in a position to account for the development of the special mechanisms involved in the adaptive actions of organisms, or even to explain their mode of operation in their finished and active state as parts of the adult organization. Thus there is still uncertainty about the mechanism of muscular contraction (although the indications are that a muscle is an electro-capillary motor); and everywhere similar difficulties confront us. These arise chiefly from the unexampled complexity and delicacy of living structures and mechanisms, whose characters furnish at once a support to vitalists (like Haldane and Johnstone), and a challenge to the mechanists, who see in the regularity of vital action a proof of its complete conformity to physico-chemical law. It would seem, however, that the *scientific* difficulty is mainly one of analysis and will become less with time and the progress of research. Probably the chief reason why the structural features, chemical properties and activities of organisms are so remarkable and so difficult to duplicate in artificial systems is that the material composing the living organized structures is always *metabolizing* material, of the kind characteristic of life. Structures which would be impossible (because impermanent or unstable) in material having no such automatic power of self-replacement are capable of permanent existence in living organisms; hence the possibilities of organized structure and activity are enormously increased. The structural organization present in the nervous system of a thinking human being is of a type whose stability is rendered possible only through the ceaseless metabolic activity of the living substance, in which the tendency to reach static equilibrium is continually offset by new construction. Regularly acting mechanisms which otherwise would be too delicate and complex to have more than an evanescent existence are thus rendered permanent; and with their continued existence and operation possibilities of activity are introduced which would otherwise be unattainable. Such possibilities are indefinitely great, and correspondingly the capabilities of a highly developed and trained nervous organization have no assignable limits.

These considerations make it clearer what kind of a system,

in the physico-chemical sense, the living organism represents. Evidently the constituting elements or essential distinguishable components of a living organism—considered as a system in equilibrium with an environment—are only in part static conditions; they consist largely of events, processes and sequences, often prolonged and highly complex. The phenomena of life show in a most striking manner how temporal processes or successions of processes can be organized into stable groupings or equilibria, just as certainly as can static conditions. Take an elementary instance: in a human being the swallowing of food initiates a sequence whose details are largely known to physiologists; upon the regular succession of interconnected events and processes which follow, constituting digestion, absorption and the rest, depends the continuance of the individual life. The first stage of the total sequence determines the final and intermediate stages, in a manner which is none the less constant and dependable because it is indirect; if the normal sequence be deranged, the organic equilibrium is disturbed and death may result. Such an illustration indicates clearly the kind of organized or equilibrated whole which an organic individual represents. A still more striking illustration of the living or organic type of constitution is seen in the regular sequence of developmental processes connecting one generation with the next; the continuance of the species in nature depends upon the regular repetition of this sequence. Yet in spite of the inconceivable complexity of the process of embryonic development, it is a perfectly definite, constant and unified process, of such a kind that when its initial event is determined (in fertilization) the whole sequence is also determined. Of course such a sequence may be modified or interrupted by outside agencies; normally, however, it represents a characteristic "natural constant" for each species, and is an essential factor in its continuance, *i.e.*, in preserving its equilibrium with external nature. Such an example illustrates perhaps more clearly than any other the essential nature of vital organization; it is an organization or integration of *processes*. There is no limit to the complexity of the single processes, provided their constancy is assured; and also no limit to the complexity of the integrated product, the living organism. Apparently there exists a popular impression that when consequences are indirect and require time for their appearance they are less certain than if they are direct; the above instances show that they are no less certain; the difficulty is to trace the intermediate events and their interconnection. Highly indirect consequences of the most perfect uniformity and reliability are frequent, one might say the rule, in living organisms. And it is as an organization of processes which are equilibrated, *i.e.*, so interrelated and integrated as to secure persistence and unity to the whole living system in its environment, that life occupies its unique position among the phenomena of nature.

Many of the most characteristic manifestations of life in nature are referable to the innate tendency of living matter, as growing or self-multiplying material deriving sustenance from outside sources, to increase indefinitely in quantity. The limit to this increase—supposing other conditions, like temperature, to be favorable—is set by the supply of available transformable material; presumably if all substances were equally assimilable, the whole of nature might thus be transformed into living protoplasm and the products of its activity. Coal fields and tropical forests are illustrations of how far this process has extended at certain times and localities; and in a somewhat different sense the transformation of the world through human activity illustrates the same tendency.

Since each organism transforms the materials that it assimilates *specifically* into its own kind of living organized system different from others, the inevitable result follows that those organisms which are most effective in securing and transforming these materials increase at the most rapid rate. If we put a yeast cell into a solution containing sugar and the appropriate salts, in course of time these substances are transformed into yeast protoplasm; if several cells of different species are introduced, several different kinds of protoplasm are produced, in quantities determined by the relative transformative or metabolic capabilities of the species. Such facts indicate that whenever organisms are present a tendency results for all assimilable compounds in the environment to be transformed into living substance; and there seems to be no doubt that here actually exists in nature a general tendency of this kind, however it may be interpreted philosophically. To physical science this tendency appears simply as a necessary result of the property of automatic growth and propagation characteristic of protoplasm. This peculiar appropriative property of life, which is apparently an accident of the special chemical constitution and structure of its physical basis, introduces into living nature the element of competition or struggle, which since Darwin's time has been recognized as a main factor determining the direction of organic evolution. Only those organisms can persist in free nature which possess the means of securing the material and energy required for their maintenance and increase; accordingly, since the supply of transformable material is limited, the characteristic situation arises which is described (in anthropomorphic terms) as the struggle for existence, with its result, the survival of the fittest. It is curious to see how what appears to physiological science simply as an automatic activity of systems possessing a certain physico-chemical constitution has resulted in the spread of life over the whole earth, with all of its extraordinary diversification. The original appearance of life might thus conceivably have been due to some primarily accidental collocation of materials, producing a system having the power of automatic specific transformation and growth. Any such system having thus arisen would inevitably persist and spread, provided the substances and physical conditions necessary for its growth were present. For example, the production, through some chemical accident, of a photochemical transformer like chlorophyll would enable the organisms possessing this compound to spread wherever there was a supply of carbon dioxide, salts and water. We observe in fact that green plants cover the whole earth, and that the greater part of organic life is directly or indirectly dependent upon them.

There is an apparent quality of exclusive self-reference in all organisms, due to the specific assimilative element in their constitution. This fact is in no way inconsistent with the development of interdependent relations between the individuals of a species, as seen in the social animals, or even between different species, as in symbiosis. Such conditions may be regarded as forming the physical basis on which altruism has evolved in the higher forms of life; it should be noted, however, that they can persist only in so far as they favor (or at least are compatible with) organic survival. What we describe as the egocentric property of conscious organisms appears to objective science simply as a manifestation of the characteristic vital assimilative capacity, which, being specific for each organism, has the effect of making each act as if it were the expression or objectivation of a definite "purpose," that purpose being to maintain and multiply itself and its own species. At least it is objectively true that unless the organic activities have this result in the long run, extinction follows, as a purely physical consequence. No one can ascribe selfishness, except by metaphor, to a weed which chokes out all the fairer plants in its neighborhood; and yet the property which such an organism exhibits, and which is physiologically necessitated by its own innate type of constitution, has an obvious resemblance to the conscious and acquisitive selfishness shown by human beings under certain conditions. The curious and seemingly inexplicable dependence of consciousness upon the physiological processes in a particular single organism—what we call personal consciousness—is a phenomenon which gives to the intellectual and psychic processes, so highly developed in man, the appearance of being essentially biological functions, developed like other functions in the interest of organic survival. The selfishness of persons, social groups and nations would thus appear as something rooted in the

elemental physical nature of organic life, and hence inescapable. But this view has its limitations, and need not disturb those who still believe in the possibility of transforming life and nature in the direction of realizing or objectifying the higher human ideals. Such ideals have a reality, a fundamental part of which is the physical reality of living beings; hence they have transformative and reproductive capacity—*i.e.*, the potentiality of indefinite multiplication and self-realization which is inherent in all life is theirs also. The qualities of the best life are thus capable of survival, increase and eventual dominance, equally with those of inferior life—probably more so, since all persistent life requires the maintenance of equilibria, and equilibria are more stable when disharmonies, destructive elements and other incompatibilities are absent.

So far I have been considering life as a development or special derivative of physical nature, and have dwelt chiefly on its physico-chemical properties and aspects. But these form only a part of its total reality; this is shown clearly by our own conscious experience. Many other sides of our problem would require consideration in a complete discussion; but time does not permit of this, and I am also not sure of my qualifications for the task. There are, however, certain more general considerations which I wish to bring forward, necessarily in a somewhat summary form, as having an intimate bearing on the more fundamental aspects of our problem.

Observation seems to show that the living organism, as a part of nature, exhibits all of the general or fundamental characters of natural existence, but in an intensified and centralized form; *i.e.*, the organism is an epitome or summarized expression of certain essential and innate properties or peculiarities which pervade the whole natural process. The complexity, specialization and diversification of living beings correspond to certain definite natural tendencies carried to an extreme; similarly with their spontaneity and originative or creative capacity. How then are we to interpret nature as a whole? A true interpretation would enable us to comprehend the two apparently contradictory aspects of organisms, (1) their physically determined or mechanistic character, existing in combination with (2) their apparent freedom of action and creativeness, the latter being seen especially in human beings. At present among biologists the mechanists and the vitalists form opposed groups; yet it seems certain that there is no necessary or irreconcilable contradiction between their views. A free or purposive agency may be mechanically actuated, *i.e.*, may exhibit complete mechanical interdependence between all of its parts and processes; nevertheless in its ultimate determination other factors than the mechanical may enter. It still seems to me that the case of an artist working with mechanically refractory material illustrates this general type of situation; he may master his material only in so far as he is familiar with its mechanical properties and behavior, and conforms his own action to these. The material undergoes no change except as acted on by mechanical forces, but these are directed and coördinated by the conscious intention of the artist.

The problem is difficult, and I can do no more at present than to indicate what seems to me the probable direction in which its solution lies. It is a problem for both physical science and philosophy, especially for a philosophy which is rigidly critical and demonstrative in its method, rather than speculative, since our purpose is to obtain a clear and valid conception of the present actuality, rather than to develop ideas which appeal to ingenious and imaginative minds as representing interesting possibilities.

Nature, as it presents itself to our observation, has its highly general or universal as well as its particular aspects. It is at once a continuum and a tissue of separate events. Repetition is its most pervading characteristic, at least when its details are considered. This repetitive character seems fundamental to reality in general; it forms the basis of logic in the mental sphere, and of stability, uniformity and regularity in the physical sphere. Yet the whole natural process does not seem to be repeated (in spite of Herbert Spencer's contention), but has a progress or trend; scientific observation indicates this, and the physical law of dissipation seems inconsistent with any other conception.

We have then in natural reality a combination of a regular or repetitive structure (equivalent to law-abiding or logical) with a forward and apparently irreversible trend or activity ("becomingness") which is perpetually generating novelty. This novelty appears to scientific observation as derived from changes in the configuration, position, and modes of interaction of certain persistent entities or objects whose characters remain unchanging. In the physical sphere these appear as atoms or electrons; the quantum theory also attributes atomism to energy. A diversity or manifoldness arising from the varying combination of similar ultimate elements, *i.e.*, some kind of an atomism, would seem inherent in the natural constitution of things.

Now physical atomism seems to be related to the general characteristics of space and time. Just as one portion of space or time is similar to any other, so any condition originating in space and time is persistent and unchanging only in so far as it conforms to this general characteristic of spatiality and temporality. Hence the electrons, *i.e.*, the ultimate persistent or unchanging spatio-temporal elements of physical reality, are all alike; *e. g.*, all electrons are equal in the physical property of mass or inertia, a quality defined by a relation, *viz.*, acceleration, dependent on fixed spatial and temporal conditions. Thus there exists in nature a stable, unvarying or permanent foundation on which development can proceed. No development, but only chaotic conditions, would be possible without an underlying permanence and stability in the ultimate constitutive elements of physical reality and in their mode of action. On this much it would seem that all scientifically and logically trained minds can agree.

The repetitive and orderly quality everywhere observed in nature is a derivative of this foundational stability. And this quality, shown in external nature as the natural laws or constants discovered and formulated by scientific observers, has its close correlative in the repetitive and orderly quality of conscious intellectual operations. These, whatever else they may be, or implicate, *are* a factor in enabling the living organism to deal effectively with external nature. All human experience shows this. Knowledge is a relation of correspondence between the knower and the thing known; there is an adjustment which interrelates the two in a manner favorable to the knower, *i.e.*, he is thereby enabled to act effectively in reference to the thing known. This kind of relation is similar to that observed in external nature between the organism and the environmental objects to which it reacts effectively. The element of adaptiveness or equilibrium is the essential feature in this relation. It would appear, therefore, that the orderliness in both the mental and the physical domains has a common origin and significance. The question of the ultimate basis of this "logical" quality in things is, however, one for metaphysics rather than for natural science.

But there is also in nature an element making for the production of novelty—a creative or synthetical ingredient; this introduces complexities which to our minds often appear as disorder and arbitrariness. Many origins seem at first sight unaccountable; yet when they are traced out in detail they are found to consist of orderly and familiar elements in new combinations. Their discordance or alien quality seems usually due to lack of conformity with other systems or processes which have arisen independently—*i.e.*, to lack of equilibration. This incompatibility gives the appearance of disorder in nature, and indeed is disorder, in the sense that anything *new* necessarily lacks conformity to established rule at its first appearance; but, given time, all existents which are in free communication settle down into some kind of equilibrium or *modus vivendi*—at least this is true in the physical world. Whether it is true of existence as a whole may be doubtful;

the element of conflict seems ineradicable so long as novelty continues to come into existence, for, *qua* novelty, it necessarily encounters conditions which are not in harmony with it and with which in some manner an equilibrium has to be reached—a process requiring time and mutual adjustment.

This combination of conservative and novel elements in the structure of reality makes a different kind of appeal to persons of different mental constitutions, and is what gives rise to the apparently irreconcilable feud between the mechanists and the vitalists in biology. Those men who are most impressed with the essential conservatism and constancy of natural processes as exhibited in the living organism are mechanists; to them the organism is simply a complex machine. Those who are chiefly conscious of the free and novelty-engendering element always present, and most conspicuously in those activities that seem characteristic of the highest vitality—*e. g.*, originality and creativeness in art—are vitalists; such men are often inclined to limit the applicability of physico-chemical methods in physiology. On our present view both are right and both are wrong; the organism in its purely physical constitution is undoubtedly a physico-chemical system, peculiar in nothing but its special qualities of complexity and highly developed specificity; yet to account for its complete characters a reference to ultimates other than the physical seems necessary.

This last consideration is the crucial one. For example, if the regular or conservative tendencies disclosed by natural science were the only ones operative in nature, it would be incomprehensible why the universe is not homogeneous, or at least is not in a state of settled and stable equilibrium, since sufficient time has elapsed for any inequalities of potential to have become equalized, and thus to balance one another wherever they come in contact. The fact that this has not happened indicates the presence of some constantly acting originative tendency in nature which in some manner compensates the tendency toward a static equilibrium.

The scientific, mathematical or logical description of nature does not pretend to exhaust the concrete detail of reality; nevertheless it undoubtedly expresses accurately many of the permanent conditions to which all phenomena (all existents?) must conform. These permanent conditions are the primary or fundamental actualities in nature; and they underlie and make possible the infinite variety of materials, events, processes and developments which it presents to our observation. All of these, except possibly the most elemental realities investigated by mathematics and logic, appear as products of what we may agree to call "creative evolution." This process is also a fact, a tangible actuality in our experience. To call the novelty-producing or creative element in reality "volitional," or to ascribe to it consciousness, purpose and ethical intention, is in a sense to anthropomorphize nature; in any case it can give only a vague indication of the essential nature of the originative factors underling development. Still, these factors, if existent in a natural product like humanity, must also be present in some form in the natural process considered as a whole. In all such speculations, however, the implications of language are misleading; and direct experience or intuition of phenomena—in active life as well as in observation and reflection—would seem to be the safest basis for sound and valid thinking. Of course by the term intuition I mean nothing mystical or indefinable, but simply direct conscious experience of the actual phenomena of life and nature, without the prejudices or preconceptions arising from the use of words or other symbols. Scientific observation or intuition (in this sense) discloses as a reality the constant or law-abiding and hence calculable element in phenomena; but superposed on this, and equally real and fundamental, is the creative element which gives nature its character as a temporal or historical process whose possibilities are never completely realized at one time, but always in process of realization. The conflict of opinion which makes metaphysics an alien and often unsympathetic field to students of the physical sciences indicates that something is still lacking in our knowledge of the essentials of reality. There must be some solution of the metaphysical problem on which all clear-sighted, honest and disinterested minds can agree.

THE ART OF PROLONGING THE LIFE OF PLANTS

THE dearest dream of mankind for untold ages has been the cheating of death. The fountain of youth has been sought for century after century even more eagerly than the philosopher's stone. Eminent scientists from Roger Bacon to Dr. Voronoff have busied themselves with the problem and startling results have been obtained in the last decade by various methods, including the grafting of certain organs, the use of the X-rays, etc.

It is our present purpose, however, to describe the success obtained by the eminent Viennese botanist, Prof. H. Molisch, in prolonging the life of plants. This authority announces that the duration of the life of a plant can be increased in various ways. The simplest method of accomplishing this consists in retarding germination by depriving the plants of certain conditions requisite for sprouting, such as moisture, warmth, oxygen, etc. In this manner seeds can be made to retain their vitality for not less than sixty years and bacteria for much longer. This interesting fact explains the apparently well authenticated cases of a sudden outbreak of the mediaeval plague in modern times.

It is also possible to lengthen the existence of those plants which bloom only once throughout their life by preventing the bearing of blossoms and fruits. A case in point is the American Agave also called the hundred year-old aloe or commonly the century plant. In its Mexican home this plant requires only eight or ten years to become mature enough to blossom, whereas in less appropriate climates, i.e., in a temperate zone, it needs fifty years or more to accumulate the substances which it has need of in order to produce flowers. Thus in this case also the life of the plant is greatly extended. For the same reason the *Reseda odorata*, which ordinarily is an annual, may be made to live for two or three years merely by suppressing the blossoms. This explains, too, why close-clipped turf can be kept fresh and green for many years. Another example of interest to garden lovers is the well-known fact that many annuals can be made to live for almost two years if they be sown in the fall instead of in the spring.

But besides these ordinary and somewhat obvious methods of prolonging the life of plants, more strenuous measures may be taken by the forcible alteration of the activity of one of the plant's organs. For example, the leaf stem of the *Begonia rex*, which ordinarily dies at the end of a year together with the blade of the leaf, may be prevented from dying if the leaf be used as a cutting. In this case leaf sprouts develop from the blade of the leaf and the former leaf stem becomes transformed into a stalk and continues to live for two or three years longer. Extensive investigation has proved that in such a case the internal structure of the leaf stem undergoes an extensive alteration fitting it to perform its new function; for instance, the sap channels become greatly enlarged. In a similar manner it is possible to maintain the vitality of the flower stem, which ordinarily quickly perishes. It is a notable fact that in many cases the dying of a cluster of flowers is retarded by the action of gall-forming insects which make their homes therein; this may be observed in the catkins of certain oaks attacked by gall.

Fruit raisers thus prolong the life of their trees:

A short-lived variety is grafted upon a long-life variety, thus assuring an extension of life in the case of the transplanted scion. Sometimes, indeed, the reverse of this may be observed, i.e., a prolongation of the life of the grafted tree by means of the scion. All these facts deserve attention and further study both from scientists and agriculturists, since they are of tremendous importance in both gardening and farming and furnish rich possibilities of advantage in all such matters.

So-Called Lung Fishes

Peculiar African Fish That Buries Itself In the Mud During the Dry Season

SINCE by far the great majority of fishes obtain the oxygen they require not directly from the open air, but from air dissolved in water, they breathe through gills. Gills are rows of red fringes, into each strand of which there runs a blood vessel. As the water passes over it the dissolved oxygen is absorbed through the skin of the gill fringes. The gills are attached to the gill arches, which are four rib-like bones on each side of the gullet above its entrance.

But there are some curious fishes found in various parts of the world which possess lungs as well as gills and, therefore, are called lung fishes or *Dipneusti*. In this subclass the air bladder is of a cellular nature and is used as a lung. The layman might readily suppose that these air-breathing fishes are a more advanced type than their gill-breathing brethren—a type farther along the road of evolution. Such, however, is not the case. They are, on the contrary, very ancient of origin, coming down to us from "the vast darkness of Palaeozoic times."

In the *Dipneusti* the trachea or air duct starts as in the higher vertebrate animals from the lower side of the gullet. But in some more specialized fishes it is transferred from the ventral to the dorsal side to avoid making a turn in passing around the gullet itself.

In all the *Dipneusti* or *Dipnoans* as they are sometimes called, there is but one external gill opening, leading to the gill arches. In the young there is a bushy external gill. The nostrils, as in the frog, open into the pharynx, while the heart is three-chambered, the arterial bulb having many valves. The cellular structure of the skin and other tissues is essentially similar to that found in Amphibians. While there are a number of species we shall here confine ourselves chiefly to the African Lung Fish of which we are able to present excellent photographs, and to the Australian fish known as the barramundi. This latter fish sometimes reaches a length of six feet and is highly valued as food. Queensland settlers often call it salmon, from its pink colored flesh. The barramundi is conveniently able to use the gills and the lung either together or separately. It is said to be in the habit of taking occasional promenades on land, but there is some doubt about this. We are indebted to the Royal Natural History, edited by Richard Lydekker, B.A., F.R.S., etc., for much of the information in the following paragraphs, but our photographs were obtained through the courtesy of the American Museum of Natural History, New York City:

In the lung fishes the skeleton is partially ossified, with well developed membrane bones; the gill clefts are but slightly separated, and open into a single cavity protected by an external cover; and the external skeleton consists of true bony tissue. In the existing members of the group the optic nerves (or those proceeding from the brain to the eyes) simply cross one another, without any interlacing of the constituent fibers; the intestine has a spiral valve; the air-bladder is elongated and performs the functions of a lung; and the nostrils open posteriorly by two apertures into the cavity of the mouth, after the manner of the higher vertebrates. The membrane bones covering the roof of the skull, which are very few in number, cannot be correlated with those of the bony fishes. The lung fishes are at the present day represented only by three genera, with but very few species, but they were formerly a very numerous group, which appears to have been on the wane since a very early epoch.

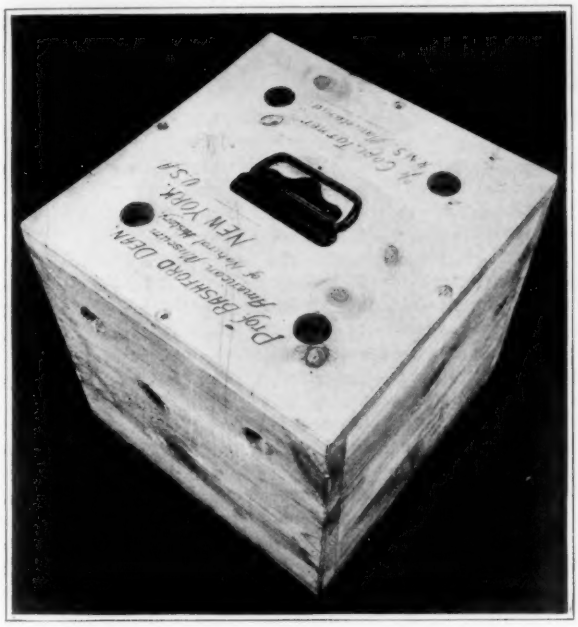
The three existing genera of lung fishes may be taken as the typical representatives of an order including several extinct

HOW THE MUD FISH BURIES ITSELF

MUD FISH COCOON EMBEDDED IN A MUD BANK

THE MUD BALL BROKEN OPEN AND SHOWING THE COCOON

families, and known as the Sirenoidea. Its essential characters are that the head is covered with membrane bones; that the main dentition takes the form of large grinding plates, situated on the pterygoid bones in the upper, and on the splenials in the lower jaw; that the body is covered externally with overlapping scales; that the notochord persists throughout life; that the paired fins are of the fringed type;



CASE CONTAINING MUD FISH COCOON FROM GAMBIA, WESTERN AFRICA

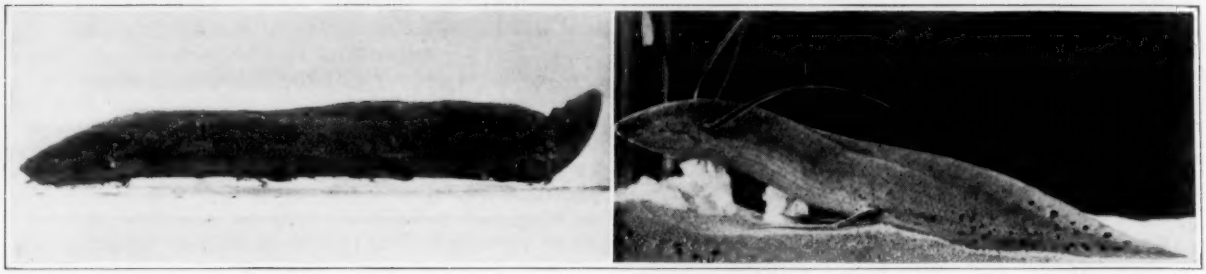
and that none of the fins are armed with spines. The existing forms have but few membrane bones to the skull; no premaxillæ, marginal teeth, or jugular plates; a fringed tail, furnished with a continuous vertical fin; and cycloid scales.

Australian Lung Fish.—For a great number of years there were known from the Triassic strata of various parts of Europe fish-teeth of a remarkable type; from the fancied resemblance to a deer's antler, presented by these teeth, the name of *Ceratodus* was suggested for the otherwise unknown fishes to which they pertained. Similar teeth were subsequently obtained from Secondary Rocks in India and also in South Africa, but it was not until the year 1870 that a fish was discovered in Queensland having teeth of a similar type. Known to the natives, in common with other large freshwater species, by the name of barramundi, the Australian lung fish (*C. forsteri*) agrees so closely with the extinct forms that it is usually regarded as generically identical. Its mouth is furnished in front with a pair of chisel-like teeth situated on the vomers, behind which comes a pair of palatal teeth of the type of the one described, but carrying six complete ridges, and an incomplete seventh; while there are a pair of similar teeth in the lower jaw, carrying only six ridges each. In the living species the teeth of opposite sides are separated by an interval; but in the fossil forms they were in contact, and had fewer ridges. The existing Australian lung fishes, of which two species have been described, are said to attain a weight of 20 pounds and a length of upward of 6 feet. The body is elongated and much compressed, with very large scales; the paddle-shaped limbs have very broad fringes; and the flesh is salmon-colored. From the occurrence of masses of leaves in its stomach it is evident that the Australian lung fish crops the vegetation with its great teeth; but it is believed that the most important part of its food consists of the small creatures living on and between the leaves of the various water plants. The stories of the fish coming out of the water to the land seem quite unfounded, as are those that it lies dormant during part of the year in cocoons. The female lays her rather large eggs loosely and singly among the vegetation, and in the embryo the fore-limbs make their appearance in about a fortnight, but the hinder part not before two and a half months. In the course of the development this fish presents marked resemblances to the Amphibians, and also to the lampreys; but it is noteworthy that there is no trace of a sucking mouth, or of external gills. As might have been inferred from the study of allied extinct forms, the large palatal teeth are formed by the fusion of a number of separate small teeth. According to Dr. Semon, the Australian lung fish is confined to the middle portion of the Burnett and Mary Rivers of Queensland. Living among the mud and leaves at the bottom, it rises at intervals to the surface to obtain more complete oxygenation of its blood by the inhalation of atmospheric air into its lungs, although its general breathing is carried on by the gills. A grunting noise sometimes uttered by this fish is probably produced by the expulsion of the air from the lungs when it rises to the surface. Although frequently termed the barramundi—a title apparently belonging to a totally different fish (*Osteoglossum*)—it appears that the proper native name of the Australian lung fish is djelleh. The breeding season is at its height in September and October, but lasts from April to the beginning of November; and the eggs which are enveloped in a gelatinous coat, and are heavier than water, take some ten days to hatch.

African Mud Fish.—The African mud fish (*Protopterus annectans*), widely spread over the tropical regions of the continent from which it takes its name, differs from the last in that the filamentous fins retain a small fringe containing rays; as well as in having six gill-arches, with five intervening clefts, while there are three small tentacle-like appendages above the small gill-opening on each side. In the Gambia River, where they are very abundant, these fishes are in the

CHISELLING THE COCOON OUT OF THE EARTH BALL

habit of burying themselves during the dry season, making a kind of nest, in which they pass a period of torpidity. Here they may remain for the greater part of the year, only resuming their normal aquatic life with the return of the wet seasons. Prof. W. N. Parker, who received some specimens in the torpid condition, writes that about a hundred individuals were dug out and packed up in crates still enclosed in the clods of mud. On arrival in Europe the clods were opened,



MUD FISH IMMEDIATELY ON EMERGING FROM ITS COCOON (*LEFT*) AND AFTER ASSUMING ITS NORMAL FORM (*RIGHT*)

and the fishes placed in a tank in a hothouse. The statement of the natives that the species grows to the almost incridible length of 6 feet suggests that it must be a very long-lived creature. From the above-mentioned specimens it was found that these mud fishes grow very rapidly, have great vitality, and, although able to sustain fasts, are exceedingly voracious, devouring all the snails, earth-worms, and small fish given them, and then killing and eating each other, making it difficult in the extreme to preserve the specimens. They are most active at night, and appear to keep mostly to the shallow water, where they move deliberately about on the bottom, alternately using the peculiar limbs of either side, though their movements do not seem to be guided by any strict regularity. Gray has compared these movements to those of a newt, and several other observers have noticed them. The powerful tail forms a most efficient organ for swimming rapidly through the water. It is a well-known fact that this fish comes to the surface to breathe at short intervals, and thus it is evident that the lungs perform an important, if not the chief, part in respiration during the active life of the animal. The air passes out again through the opercular aperture, and the movements of the operculum itself indicate the fact that branchial as well as pulmonary respiration takes place. Externally, the sexes are alike. As in the American species external gills are developed in the young. As regards the breeding-habits of these fishes nothing very definite is known. It is stated, however, that the numerous eggs and embryos are carried about in an elongated gelatinous pouch attached to the sides of the back of one of the parents, although the sex in which these receptacles are developed does not appear to have been ascertained. In conclusion, it may be observed that Professor Parker is of the opinion that although the lung fishes present certain resemblances on the one hand to some of the sharks and ganoids, and on the other to the lower Amphibians, yet they appear so distinct from both that he thinks they ought to be removed from the fishes to form a class by themselves.

FLORAL FIREWORKS

THE methods by which plants secure the distribution of their seeds and spores, so as to give their offspring a better chance to get on in the world than if they stayed too close to the parent stem, are always interesting and sometimes very ingenious. In a number of cases one sort or another of ballistics is employed to secure the discharge of the seed with considerable violence, thus giving it a good start on its travels by windpower. In the accompanying illustration we show a remarkable instance of this. As the reader can see the photographer was lucky enough to catch the puff ball at the very moment of its explosive discharge of its spores. These lycoperdons are among the most familiar of the fungi common to Europe and America. The explosive action in this case is due to the sudden splitting of the outer skin of the fungus because of the pressure of the humid spores within, which are expanded by the rays of the sun falling upon the plant. It is said that those persons with a delicate enough sense of hearing can even perceive the noise of the explosion when this vegetable bomb goes off.

Many other plants discharge their seeds with more or less violence, with the same object of propelling them to as great a distance as possible. The common touch-me-not found in all old-fashioned gardens is a well-known example of this. When the pods of peas and beans become dry, they undergo a torsion which secures their dehiscence.

Various forces are operated in securing the forcible ejection of seeds and spores; the movements by which the discharge is accomplished are sometimes occasioned by cohesion, sometimes by hygroscopic phenomena, and sometimes by turgescence as in the case of the lycoperdon.

PUFF BALL EXPLODING AND DISCHARGING ITS SPORES

Those motions in which an external factor directly induces any movement of any part of a plant are called by botanists, paratonic movements, or more simply, stimulus movements. In the touch-me-not cited above the seed pod consists of narrow segments united at the tip, and in such a state of tension that a mere touch causes them to separate at the tip and curl up into a convexo-concave shape. Other stimuli besides this one of contact are light, heat, gravity, and various material and mechanical forces.

The geranium family have pods composed of five carpels of a beak-like form which generally open to liberate the seeds; sometimes, however, the pod itself remains closed and the awn-like portion of it goes through a series of hygroscopic movements, whose object is to bury the seed in the soil.

The Mechanical Side of Evolution*

Some Remarkable Recent Discoveries in the Field of Embryology

By Dr. A. Weber

Professor of Anatomy in the Universities of Algeria and Geneva

In the following article by Dr. A. Weber, who is himself a well-known original investigator along these lines, an excellent résumé is given of the remarkable advances made by this science during the last six years. The article is too long to publish in full in these pages; we shall, therefore, omit the more technical portions of it appealing especially to professional biologists and confine ourselves to the reproduction of the introductory paragraphs together with those sections of general interest, giving merely a brief résumé of the first six sections.—THE EDITOR.

IN the *Revue General des Sciences* for October 15-30, 1914, we called attention to the critical period through which the science of embryology was passing. The rapid development of this science was due principally to the enthusiasm created by the spread of the theories announced by Darwin and by Haeckel. Many investigators believed that the question of the origin of species found its solution in embryological discoveries. These attempts to fathom the past history of living creatures justified the almost unanimous belief in what is known as the *fundamental biogenetic law* or law of Haeckel: *i.e.*, that the development of the organism follows the history of the development of its species; in other words that ontogeny recapitulates phylogeny.

It was long ago clearly demonstrated by paleontologists, Depéret, among others, that many embryologists had confounded the phylogenetic development of species with that of organs considered separately. It has been oftenest among species unrelated to each other as a matter of fact that it has been found possible to establish in this manner the evolution or the involution of portions of the skeleton or of the viscera.

The critical comments of such embryologists as O. Hertwig, Keibel, and Vialleton, indeed, have practically torn to shreds the aforesaid fundamental biogenetic law. Its almost unanimous abandonment has left considerably at a loss those investigators who sought in the structure of organisms the key to their remote origin or to their relationships. Although that future opinion may be less positive with respect to the phylogenetic value of embryology. After all, as Hertwig observes, the reason why we now class the Sacculina, a parasite of the Crab, among the Crustaceans, is solely because of the study of its development.

It appears to be a fact also that embryological researches have been influenced by the new direction taken by concepts of heredity. The wide spread extent and the success of the experiments undertaken in order to verify Mendel's laws of heredity have been of no little help in creating an entirely new attitude among embryologists. It is practically certain that purely descriptive embryology has now yielded the major part of the knowledge that can be expected from it. It is above all an analytical process in the service of Comparative Anatomy. However the information it furnishes with respect to the homologies and analogies of organs or their functional adaptations, and to their physiological or morphological values is of interest. On the other hand a new form of embryology has recently made its appearance. This science is what the Germans term the *mechanics of evolution* and what Brachat calls *causal embryology*. From this new point of view investigators no longer devote themselves to explaining the past history of organisms but rather to exploring the present causes of their development. Thus what embryology has lost from a speculative point of view it has undoubtedly gained in precision by following the modern method of research.

This review will be concerned principally with the recent works inspired by this new attitude of mind. The largest number of these works has appeared in the German language. Professor Roux was one of the first men of science to adopt this new viewpoint and he has carried with him many of his students. The periodical in which most of their experiments have been reported, namely, *Archiv für Entwicklungsmechanik der Organismen* (Archives of the Mechanics of Development of Organisms) did not cease publication during the war. While nearly all of our French scientific journals failed to appear, the Germans continued to exhibit but slightly diminished activity; for while the war was a matter of life and death to us, it was to our enemies merely a matter of business.

Such considerations enable us to comprehend how the scientific value of Brachet's work *L' oeuf et les facteurs de l'ontogenèse* (The Egg and the Factors of Ontogenesis) is increased by its moral success. Brachet, professor of anatomy at the University of Brussels, who took refuge in Paris after the invasion of Belgium, edited and published in 1917 the remarkable series of lectures given by him at the College de France. This admirably documented little book is at once an excellent résumé of the principal researches with regard to Causal embryology, and an excellent point of departure for new researches in their varied directions.

In the following lines we shall make use of this book as a guide in the analysis and classification of works dealing with the factors of ontogenesis.

I. AGAMOUS REPRODUCTION AND SEXUAL REPRODUCTION

In the beginning of his book Brachet sets forth the analogies and the differences between sexual reproduction and nonsexual or agamous reproduction. . . . It appears to be true that sexual reproduction is conditioned either by an abundant and durable nutrition, a rapid growth and an extended life, or inversely perhaps by variations of the temperature or chemical alterations of the milieu and of the nutrition. The identical results of these contrary influences is due to a mechanism whose discovery is very recent, namely, *physiological isolation* of the portions of an organism, it being only requisite for an organ to escape to the dominating correlations of the other organs to become capable of revealing latent powers such as those of *reproduction* or *regeneration*. . . .

The principal authorities quoted in this section are C. M. Child and E. Rabaud.—EDITOR.

II. CONDITIONS OF FECUNDATION

This section discusses the question of Polyspermia, the principal authorities quoted being A. Brachet, M. Herlant, F. R. Lillie, and Bataillon.—EDITOR.

III. PHYSIOLOGY OF THE EGG

Under this title Brachet examines the present state of our knowledge with respect to the characteristic manifestations of the life of the egg cell which has arrived at maturity. This cell dies unless the phenomenon of fecundation or some similar

*Abstracted and translated for the *Scientific American Monthly* from the *Revue Generale des Sciences*, December 15 and 30, 1919.

phenomenon occurs. As Fauré-Frémiet expresses it, the egg which has arrived at the state of equilibrium which constitutes maturity is in a state of latent life; when left to itself it undergoes a sort of "agony" which is the more prolonged the less oxygen it is in contact with.

Many cytologists, including R. Hertwig, Popoff, and Child, have compared the mature egg to those infusoria which are in a state of depression or senility and which are rejuvenated by conjugation. . . . This condition of senility of the egg cell is revealed by an almost total lack of permeability. Fertilization reëstablishes this permeability. In the same way Batailon has proved that the ripe egg is in a state of osmotic hypertension. The contraction of the egg after fecundation and the expulsion of the perivitelline liquid occasion a dehydration of the egg and a lowering of its osmotic tension.

Furthermore, the expelled perivitelline liquid is charged with débris and particularly with carbon dioxide. In the state of equilibrium of maturity the egg may be regarded as an asphyxiated cell which the act of fertilization enables to rid itself of the toxins it contains. The fecundated egg has once more become permeable and expels the débris accumulated in its cytoplasm. These excreta do not always appear in the form of a perivitelline liquid but are sometimes found also in the membrane of the fecundated egg.

The remainder of this section deals largely with experimental parthenogenesis which has already been discussed at some length in this journal and its predecessor.—EDITOR.

IV. DYNAMIC MANIFESTATIONS OF FECUNDATION

Under this title Brachet analyzes the principal manifestations in the egg which has lost its equilibrium of maturity by reason of the penetration of the male element. . . .

The remainder of this section, which is very technical, discusses among other things the phenomena of dispermia and trispermia, etc. It is illustrated with a number of interesting diagrams.—EDITOR.

V. FECUNDATION AND PARTHENOGENESIS

The chief authorities quoted in this section are Faruć-Férmiet and F. McClendon.

VI. SIGNIFICANCE OF SEGMENTATION

The question arises as to the meaning of the segmentation which exhibits itself when the egg begins to develop. This segmentation is merely a dividing up of the egg without any formative value. At this period of the development there is no creation and no displacement of germinal localization. Apropos of this the question suggests itself as to what are the relations of the first plane of segmentation with the plane of bilateral symmetry of the larva.

Brachet's experiments along this line are very remarkable: in the fecundated egg of the frog, whatever the orientation of the first planes of segmentation with respect to the plane of bilateral symmetry, the latter is maintained throughout the entire course of the development.

Segmentation makes no change in the germinal localization. Thus the first stages of the development appear to form a preparation for the ulterior differentiation of the blastomeres by imparting to the cells of the embryo the normal size of the cells proper to each species, doing this by actual transformation of the voluminous egg cell.

Each blastomere which is divided by the segmentation possesses an *actual potentiality*, which corresponds to the part which it plays in the typical development of the embryo. The *total potentiality* corresponds to properties whose existence usually remains unrevealed. This latter potentiality is very variable in different animals; in some it is infinitely small, while in others it is so great that one of the first blastomeres is capable in itself alone of producing a complete larva.

In order that the total potentiality shall exhibit its full effect it is necessary for the blastomere to possess those material resources which are requisite, and it is also necessary that the distribution of these resources shall be so managed as to maintain a state of equilibrium analogous to that of the egg. Thus we may consider that polyembryomy is nothing more than a case in which the actual potentiality and the total potentiality are superposed.

In conclusion Brachet examines various hypotheses with respect to the physico-chemical nature of the germinal localization. In his opinion the term idioplasm is a synonym of the protoplasm of the egg, the type cell of each normal species.

The fundamental protoplasm of the species is transformed in the majority of cells under the impulse of correlations between the various tissues and organs of the living creature. The impression of the correlation, less marked in the sexual products or in those organs which form buds, enables the cellular elements in question to revert to the typical state under the influence of various circumstances.

VII. THE MODELING OF THE EXTERNAL FORMS OF THE HUMAN EMBRYO

In a highly original treatise Mr. Bujard has passed in review all young human embryos known to us, studying them from the viewpoint of their external forms by means of geometrical methods. He begins by describing a certain number of axes and of angles which may be observed upon the young embryos. By a comparison of the various stages of the embryo regarded from this point of view, he derives the idea of *embryotectonic curves* (*i.e.*, construction curves) which are characteristic of each of the periods of development. (Fig. 1.)

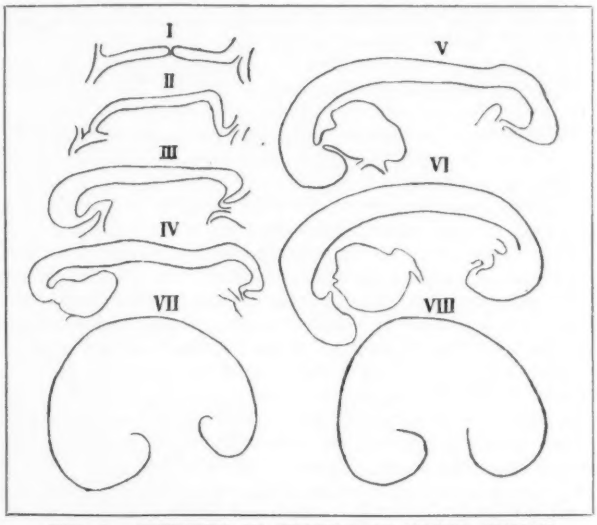


FIG. 1. OUTLINES IN PROFILE OF YOUNG HUMAN EMBRYOS EXHIBITING TYPICAL DEVELOPMENT (AFTER BUJARD)

The study of these curves enables him to apprehend numerous individual variations as well as grave anomalies which, because of the small number of very young human embryos known, have been considered as forming a normal part of the typical stages of the evolution; *e.g.*, the excessive dorsal "saddle-back" of what are known as double C embryos. Thus, the embryo tectonic curves form a criterion which enables us to decide whether any given embryo is normal or abnormal; furthermore, they constitute an expression of the mechanism of the development of external forms.

By means of these curves Bujard has succeeded in analyzing the successive periods of the changing form, or "modeling," of the embryo. During the first period, which is principally a period of growth, the embryonic area expands and grows and the first rudiments of organs make their appearance— the neurenteric canal, the primitive line, the medullary plate, the dorsal cord, and the mesoderm.

During the second period the modeling is very active and the organs assume an individual aspect. At the same time the embryo assumes a spiral form. There is an intense proliferation at the level of the neurenteric canal in the caudal

region. The embryo is thus projected forward; its head describes a parabolic trajectory in space and its tail curves in the form of an arc of a circle around a center which is the point of suspension of the embryo at the level of the origin of the allantoid. At this stage the curve of the back is elliptical.

The movement of forward projection and elongation of the embryo is arrested by the phenomena of the appearance of the rudimentary outline of the heart. The head now assumes a spiral position and this process is propagated by degrees to the dorsal region.

During the third period the spiral torsion of the embryo reaches its maximum, and then the beginning of a movement of deflection makes its appearance.

Furthermore, the examination of these embryotectonic curves enables the investigator to make extremely interesting observations with respect to the comparative topography of the various organs of the embryo. For example, the modeling of the head of the human embryo is accomplished by a series of sliding movements, which gradually bring the posterior skull beneath the pharynx and the branchial region. These sliding movements occasion a gradual effacing of the cephalic somites. Another interesting observation having a general application is that concerning the rhythm which appears in the growth of the embryo—periods of growth follow in regular succession upon periods in which the modeling process is most marked.

VIII. EMBRYONIC GROWTH

The researches of Robertson Brailsford are of particularly great value with respect to the entire evolution of the individual. According to this authority the greatest rapidity of growth occurs when the total growth is about half finished. The work of Bialaszewiez with regard to the embryos of amphibious animals is particularly apropos of the study of growth.

The first stages of the development of amphibious animals exhibit an almost perfect spherical form, whose diameter can be measured with comparative precision. During the first few hours after fecundation this diameter increases regularly and then the animal pole is flattened and the volume of the egg is diminished. At this moment it extrudes perivitelline liquid, a process which corresponds to the dehydration and purification of the cytoplasm of the egg.

Immediately after this occurs the volume of the egg begins to increase again. This growth is particularly rapid during the phenomenon of the gastrulation; when the form of the larva has been constituted, the measurement of diameters must be replaced by the measurement and the weighing of the density. These researches prove that at this stage there is a decrease of volume. Immediately after the hatching, the moment when the larva leaves the membranes of the egg, there is a very rapid growth, which certain observers, including Davenport and Schaper, have connected with a considerable absorption of water. Moreover a portion of the envelopes is utilized to nourish the larva. In the early stages of the development the increase in the volume is produced by the accumulation of water in the cavity of segmentation.

Influence of Temperature.—The manner in which the rapidity of growth of the embryos of Amphibians is influenced by temperature has been especially studied by Bialaszewicz, Chambers and Doms. These researches verify in general, between 10° C. and 20° C., the law of Van t'Hoff and Arrhenius regarding the rates of speed of reaction. Bialaszewicz has found that whatever the rapidity of development under the influence of variable temperatures the quantity of water absorbed by the larva is constant, and this quantity forms a measure of its growth. A rise of temperature accelerates the formation of the blastomeres at the stage of segmentation in the same proportion in which it increases the hydration of the cells. This absorption of water presumably bears a definite relation to the respiratory exchanges of the larva. Furthermore, the increase of temperature occasions a greater permeability of the egg with respect to the surrounding medium.

The eggs of frogs vary in size according to the region of the ovary from which they come. Chambers has subjected various sample lots of these eggs to variations of temperature. The tadpoles from the largest eggs develop more rapidly as soon as they begin to eat and they also resist the high temperature better. The smaller eggs produce larvæ having smaller cells, but these differences of size in the larvæ diminish in the course of their development. On the other hand temperature has an influence upon the cellular dimensions of the tadpole. The higher the temperature the smaller the cells are.

Doms has verified the application of Van t'Hoff's law to the first stages of the development of frogs' eggs. At this time an increase of 10° in the average temperature causes a growth three times as rapid; but this proportion ceases to be verifiable when the tissues and the organs have begun to be formed. Each tissue then reacts in a special manner which is due as much to its own constitution as to its organic correlations; *e.g.* the branchial tufts ramify more abundantly and more rapidly under the influence of a rise in temperature. Cold arrests the production of these appendices.

Among embryos which have been subjected to cold the original liver and kidney are larger than in the case of larvæ which have been subjected to heat; furthermore, differences of structure are found which concern the variable tissues, which explains the aforesaid differences of volume and which shows how the variations of temperature behave differently according to the elements involved; *e.g.*, in the kidney of larvæ which have been chilled it is the lymphoid and conjunctive tissue which is found to have increased, while in the embryos which have been heated it is the active portion, the canaliculæ and the vessels, which are more developed. In the liver of the chilled tadpoles the epithelial elements predominnate, while in the liver of the heated embryos it is the vascular tissue which has the best of it.

IX. THE INFLUENCE OF MECHANICAL AGENTS UPON DEVELOPMENT

Under this head we shall here consider only the phenomena of compression and centrifugal force.

Compression.—The production of anomalous forms or "monstrosities" has often been attributed to the phenomena of compression, but this view, which applies particularly to the eggs of birds, appears to have fallen into entire disfavor. Numerous experiments among various classes of living creatures have proved that the phenomena of compression are capable of producing deformation but not of occasioning profound modifications in the process of development.

Rabaud has considered this question in reference to the production of omphalocephaly, a monstrosity in which the head of the embryo is inserted in the digestive tube, after having been strongly flexed and partly atrophied. Fol and Warynski were of the opinion that they had accomplished this arrangement by compressing the head of the embryo chick. S. Kaestner believes, like the foregoing authorities, that the momentary cooling of the egg undergoing incubation produces an expansion of the yolk which compresses the embryo against the shell. Raband found no difficulty in demonstrating the absurdity of these observations, which are of far too superficial character. By means of carefully planned experiments he has proved that while the compression is capable of causing a retardation of growth (without doubt by interfering with the nutrition and, most of all, with the direct respiration of the cellular elements), still the monstrosity of omphalocephaly never appears under these conditions.

In a general fashion the compression of eggs in a state of development has chiefly been employed with a view to modifying the planes of segmentation of the blastomeres. In those species in which the first blastomeres have a definite destiny it has been of particular interest to disturb the development in this manner and then observe the ensuing results. Morgan

applied these conditions to the eggs of the *Nereis* and the *Ciona;* when the compression of the egg takes place before the first segmentation division, there is no injurious effect, provided the pressure is removed after the occurrence of the separation between the first two blastomeres. But when the compression is continued, the third cleavage of the blastomeres, instead of being equatorial in direction is meridian, like the two first cleavages. The larvæ obtained under these conditions are abnormal, the germinal localizations of the fecundated egg having been partially displaced by this atypical segmentation. A moderate compression does not prevent development of these eggs, but brings about a disturbance in the differentiation of the organs.

Other authorities, Browne and Dederer have likewise verified the influence of compression upon different eggs with respect to the orientation of the divisions of the blastomeres. Girgoloff observed like Rabaud the diminution of vitality in the blastomeres under the action of compression alone. The influence exerted upon the development of the *Ascaris* larva is the more marked the further advanced the segmentation is. When this mechanical action makes itself felt only at the beginning of the development the blastomeres later resume their normal position and the embryo is not malformed.

Compression, like centrifugation, governs the orientation of the spindles of division of the blastomeres. Experiments with respect to the effect of centrifugal force have been chiefly employed in the study of development in order to analyze the material constituents of the egg, to disturb the germinal localizations, and subsequently to observe the development which begins with fecundation.

Centrifugation.—Centrifugation has the effect of considerably augmenting the force of gravity. The constituents of the cytoplasm, and particularly all those which are termed deutoplasm (*i.e.*, the secondary or nutritive plasm or albuminous part of the yolk which provides food for the embryo) are arranged according to their density in parallel strata, which are often different in color. McClendon clearly proved this with the eggs of the sea-urchin and of the frog. It appears that this separation of substances having different densities in no way alters the germinal localizations of the egg. Conklin was able to modify by centrifugation the eggs of Molluscs the differently colored layers of the cytoplasm, but the first plane of segmentation and the bilateralness which is early manifested by a marked degree of asymmetry are not altered or modified in any manner. In proportion as the differentiation of the egg increases and as a new sort of germinal localization is elaborated (doubtless under the influence of fecundation) the centrifugation becomes more effective and the development more greatly disturbed.

Some authorities have even suggested that the profound modification produced in the first stages of development might be capable of modifying the sex of fertilized eggs, but Whitney has shown that this is not true.

When the centrifugal force ceases to act upon the eggs there is a reaction of the germ, which tends to resume a typical form. This regularization entails the bringing back to position of the substances which were displaced by the centrifugal action. Thus, when an experiment is made upon an egg in the stage of four blastomeres and when the equatorial partition is formed immediately after the experiment, the displaced substances are not able to redistribute themselves in the newly separated blastomeres and the germs consequently die. B. Konopacka proved this with frogs' eggs.

In these experiments there would also be a deviation of the first plane of segmentation; the female pro-nucleus being displaced by the centrifugal action the spermatozoid, whose trajectory decides the direction of the first plane, is obliged to change its path.

Certain interesting observations of Morgan show that the karyokinetic figures are displaced like solid bodies under the influence of the centrifugation and act upon those regions of the egg where various substances are accumulated, such as the pigment, the citellus (the yolk) or an oily material, without these modifications of the cytoplasm influencing the cellular division and the separation of the blastomeres.

X. INFLUENCE OF VARIOUS RADIATIONS UPON DEVELOPMENT

Ultra-violet Rays.—Stevens made use of the ultra-violet rays in the study of the development of the *Ascaris megalocephala.* One or more blastomeres are arrested in their development according to the stage of the development at the time of the exposure embryo is complete or abnormal. A prolonged exposure of the eggs to these radiations does not kill them immediately, but does definitely arrest their development; the mitoses are completed, and the blastomeres are able to change their position in the interior of the shell, but no further segmentation is produced. To sum the matter up the action of the ultra-violet rays does not modify the cellular divisions in their course but alters the following mitoses whose chromosomes are irregularly fragmented.

Fauré-Frémiet confirmed these observations; Guyénot has made a study of the eggs and larvæ of a fly (*Drosophila ampelophila*). Eggs which had been laid were exposed to ultra-violet rays and failed to develop. On the other hand, the only modification which appeared among the larvæ similarly exposed was a greater degree of mortality. When flies which were about to deposit their eggs were subjected to the ultra-violet rays they produced eggs which developed normally or proved abortive, according to whether they were laid immediately after the irradiation or several days later. There are still more remote results: Flies descended from eggs which had undergone irradiation in the body of the mother exhibited melanic forms and a partial or even total sterilization.

X-Rays.—It is in the cellular division, likewise, that the influence of X-rays is manifested as shown by Gaskell. The mitoses are retarded or even inhibited.

Under these conditions the development of the embryos is considerably retarded if not entirely arrested; but as there is nothing specific in the action of these rays the proportions of the various organs or tissues are not disturbed.

Radium.—The action of radium upon the development of embryos has been the subject of a considerably larger number of researches. The experiments of J. Tur with various germs both vertebrates and invertebrates are especially notable. He finds that the effects of radium are not immediate. There is a period during which the action is purely latent, and subsequent to this specific destructions of cells make their appearance, being limited to certain formations, principally to the embryonic nervous elements and to the first rudiments of the muscles. When the irradiation has been sufficiently early and effective, all trace of the embryo is destroyed: Germs minus an embryo or anidian germs. Certain eggs are more sensitive to the action of radium than others—thus duck eggs exhibit more complete alteration than hen's eggs, doubtless because of the slower development of their germ.

Hertwig has discovered in the eggs of amphibians the period of latency in the action of radium. As in the experiments of Tur it is the rudiments of nerves and muscles which are first altered. The sustaining tissues and the rudiments of the alimentary canal are much more resistant. The alteration of the cells was found to be concerned almost exclusively with the nucleus. Payne confirms these results, having observed under these conditions an irregular crumbling of the chromosomes. Packard, on the other hand, affirms that the alterations due to radium occur in the cytoplasm as well as in the nucleus. They seem to vary, moreover, according to the species. Under the same conditions Packard has obtained a cytoplasmolysis in the eggs of the *Nereis,* whereas in those of the *Arbacia* only the chromatine of the nucleus is affected apparently.

Veroni has found that in the action of radium upon the germ of the hen's egg there were produced not only phenomena of retrogression but also excitations of tissues causing an

increase in certain elements such as those of the mesodern. At the same time these cells lose their specific aspect, becoming non-differentiated and assuming the aspect of cancerous cells. After partial destructions have occurred, notably in the rudiments of the nervous system phenomena of regeneration have

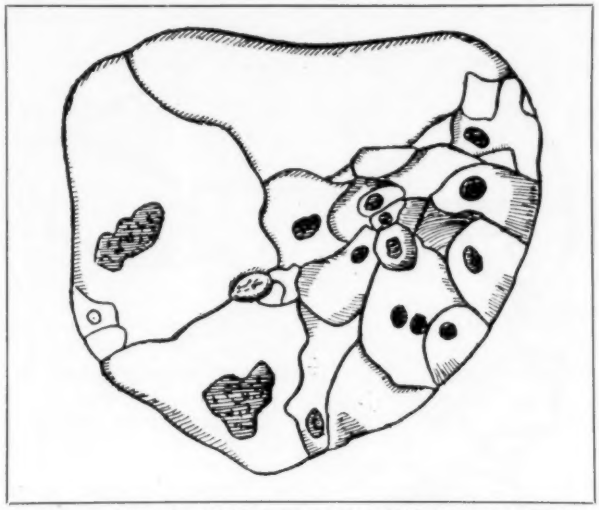


FIG. 2. GERM OF TOAD WHICH HAS MADE ITS SOJOURN FOR THREE DAYS IN THE PERITONEAL CAVITY OF AN ADULT. IRREGULAR SEGMENTATION (AFTER BELOGOLOVY)

been observed. Furthermore, the action of radium enables us to make interesting observations with respect to the cellular differentiation of the embryo.

XI. INFLUENCE OF CHEMICAL AGENTS UPON DEVELOPMENT

We shall not here consider experiments in artificial parthenogenesis by means of various substances, but rather examine certain experiments in which chemical products exert an effect upon the germ in the process of development. The choice of these substances is either purely empirical or occurs in accord with a preconceived theory.

Thus Coventry has studied the influence of acetic acid and hydrochloric acid and of soda upon the tadpoles of toads. Jenkins used chloride or sodium in various solutions to act upon the developing eggs of the frog. Reinke and also Stockard have observed modifications in the development of the tadpoles from the use of ether. By employing saline solutions Loeb has obtained a di-embryony in the sea urchin. All of these researches give the impression of having been conducted somewhat at hazard and their results have rather a curious value than a general application.

Far more interesting are the observations of Werber, who is of opinion that natural monstrosities result from the action of substances proceeding from a pathological metabolism of the parents, as, for example, from butyric acid or acetone. These substances have a very definite teratogenic (*i.e.*, producing monsters) action, which is manifested from any of those areas in which the embryonic cells exhibit the most active metabolism, as, for example, in the head. The result of this action is *blastolysis* which reveals itself in various monstrosities. Experiments in which chemical substances are made to act upon eggs or germs demand a previous study of the conditions according to which the substance is applied. The researches of Waelsch were deprived of all their value because he forgot this side of the question. He made use of the scarlet dye to influence developing hen's eggs. The normal development of the embryos of birds can be readily observed by making a large breach in the shell. I, myself, together with M. Ferret, have demonstrated that it is not the same when the lesion of the envelops of the egg is very reduced—*e.g.*, after being pricked by a needle. It is only just to add that our researches, which were published in the French language, bear the date of a period when German science was in ignorance of affairs beyond the Vosges.

Waelsch employed scarlet red dye dissolved in oil as a result of the observations of Fischer who, upon introducing this substance under the skin of the ear of a rabbit, obtained epithelial proliferations resembling a cancer (carcinoma) in aspect. It is likewise to the stimulating action of this product that Waelsch ascribes the monstrosities produced by him and which concerned the rudiments of the central nervous system exclusively. However, Ferret and myself obtained all the malformations described by Waelsch merely by pricking the egg without introducing any chemical agent. In fact one might think that the majority of the drawings in his work had been made with tracing paper from those in a treatise by Ferret, so close is their identity. It is our intention to discuss in another review the explanations given by Waelsch with respect to the mechanism of certain monstrosities. . . . But at present we will merely remark that in case scarlet red does exert an effect upon the germ of the hen's egg such action is superposed upon the influence exerted by simply pricking the inner membrane lining of the shell and the albumen of the egg. In a more recent work Waelsch describes epithelial proliferations obtained by introducing scarlet red under the skin of the larvæ of salamanders.

XII. TRANSPLANTATIONS OF EMBRYOS OR OF EMBRYONIC TISSUES

The principle governing these experiments is the inquiry into the cause of tumors in general and of teratoma (a tumor composed of a heterogeneous mixture of tissues sometimes found in new-born children), in particular. Embryologists have long been in the habit of making the experiment of grafting embryos into the adult tissues of individuals of the same species. The results obtained through such experiments are of the greatest variety and of unequal interest. Apparently the causes favorable to such translation must be sought in the differences of species. A graft of an embryo of one species almost never succeeds upon an individual of different species, even when the latter is proximate; furthermore,

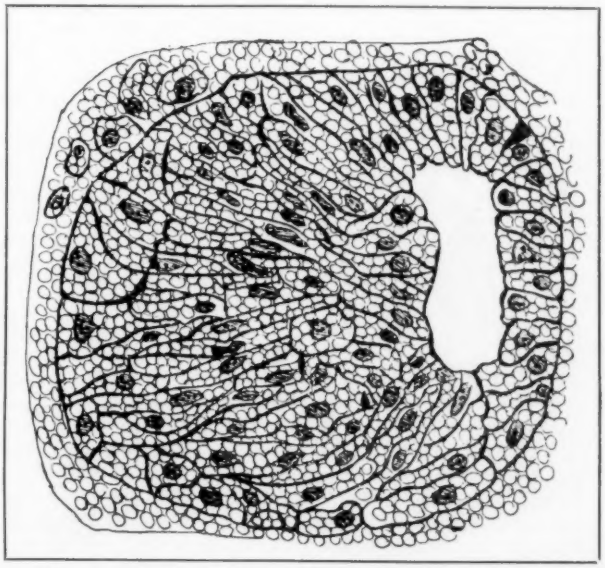


FIG. 3. RUDIMENTS OF AN ORGAN—PROBABLY OF AN OCULAR VESICLE— WITHIN A SYNCYTIAL MASS FOUND IN THE GERM OF A TOAD TWENTY-THREE DAYS AFTER TRANSPLANTATION. (AFTER BELOGOLOVY)

grafts of embryos of the same species will develop in the peritoneum. It appears to be true, also, that in the case of each animal there are different regions in which such transplantations find the optimum conditions. The nervous system of the adult appears to have no influence upon the development of the embryonic graft.

Grafting Eggs Into the Adult Peritoneum.—Among all recent researches that which we regard as offering the greatest interest to the readers of this review is that of G. Belogolovy. His experiments consists in the introduction into the peritoneal cavity of adult frogs and toads, eggs of the same animals in the process of development. The eggs of the frog are not killed in the organism of the toad, nor those of the latter in the body of the former. This certainly could not be the case among mammals, which are more differentiated from each other with respect to the chemical composition of the internal milieux.

Belogolovy deprives the eggs of their albuminous envelop and introduces them into the adult animal while they are still in the first stages of their evolution: morula, blastula, gastrula, neurula.

These germs thereupon become true parasites in a milieu which is very favorable to the life of their elements. As a result there is a simplification of their form and of their structure—a veritable functional adaptation to an easier kind of life. This investigator's observations were continued for several months with results extremely varied and interesting. His interpretations, however, appear open to frequent objections.

We will give here a brief résumé of the facts themselves (Figs. 2-5):

The typical development of the egg of the Anura, *i.e.*, tailless amphibian, which has become a parasite in the peritoneal cavity of the same adult animal is modified in a degree proportionate to the earliness of the stage at which the germ in question has been transplanted. This germ becomes dissociated into cellular masses or into isolated cells; the one and the other of these may behave in very different manners—they may on the one hand appear as tissues or as fragments of typical organs such as cartilage, glands, bones, portions of muscles, the dorsal cord, or cerebral vesicles; or they may, on the contrary, constitute formations which differ completely from normal tissues such as cysts, plasmods and cells of sarcomatous aspect.

The action exerted by the embryonic parasite upon its

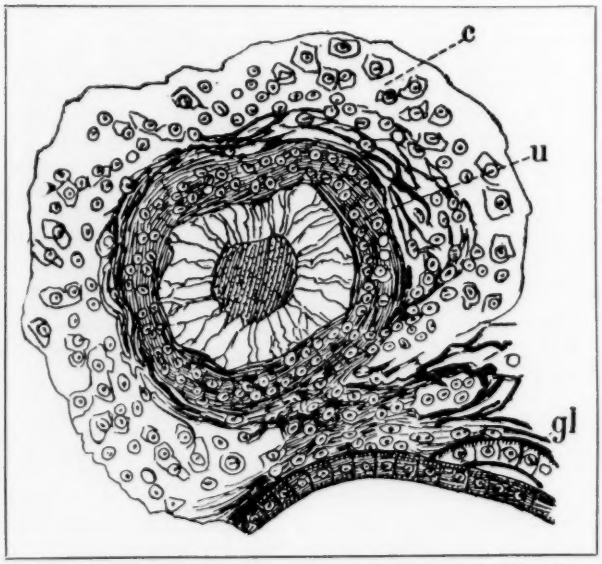


FIG. 4. EMBRYONIC FORMATION WITHIN THE GERM OF A FROG FIFTY DAYS AFTER TRANSPLANTATION

c = cartilage; *u* = urinary canalicula; *gl* = epidermic gland. (After Belogolovy)

adult host is peculiarly interesting. The embryonic cells of sarcomatous aspect penetrate the tissues of the host, destroying the latter's organs and finally killing it in the course of a few months. The adult organs in contact with the embryonic parasite exhibit a growth and power of regeneration much more active than under normal conditions.

It would be of interest to apply the ideas of Child referred to at the beginning of this review to the explanation of the dissociation of germs observed by Belogolovy. In the mind

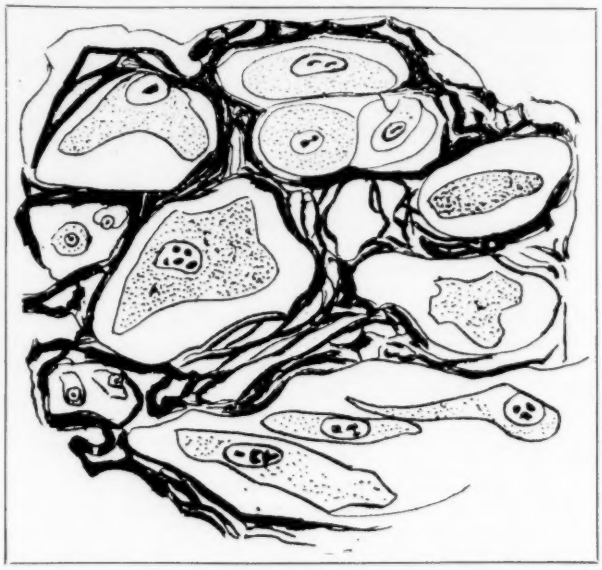


FIG. 5. DETACHED CELLS OF SARCOMATOUS ASPECT IN THE GERM OF A FROG, TRANSPLANTED 83 DAYS PREVIOUSLY, WHICH HAS PENETRATED THE TISSUES OF THE ADULT HOST (AFTER BELOGOLOVY)

of the latter the concept of individuality is quite simple, namely, that the living organism is a portion of space limited by an ectoderm or outer skin.

Inside of this ectoderm is a milieu very favorable to the life of cellular elements; outside of it there are conditions much less propitious to living matter.

In the experiments we have just cited the external milieu would be as favorable to life as the internal milieu; thus the ectoderm having lost its reason for existence perishes and ceases to limit the living creature which, therefore, becomes dissociated and abandons its individuality.

The interpretations by which this authority explains cystic or plasmodial formations, which are compared to many-celled organisms adapting themselves to the new conditions of life created by the state of parasitism, are likewise still open to discussion. None the less the facts observed are very curious and one of the most important and striking of these undoubtedly, is the direct transformation of embryonic elements into cells of cancerous nature.

AN EXPERIMENT ON REGULATION IN PLANTS

IN an article in *The American Naturalist* for July-August, 1920, Professor E. Newton Harvey, of Princeton, offers an interesting discussion of Regulation in Plants in connection with an account of his own investigations in this field.

It is obvious to one who seriously contemplates the facts of regulation, says Professor Harvey, that the influence of one part over another in the organism must be either similar to nerve influence and depend on living protoplasmic continuity between the parts, or due to the actual transport of material from one region to another.

Harvey considers the second of these possibilities—transport of material. Two views are prevalent regarding the nature of this transport. (1) A growing stem may be supposed to form material which inhibits shoot formation and a growing root to form material which inhibits root formation. These special inhibition substances pass downward and upward in the stem respectively. Polarity is a direct consequence of the formation

of these substances and their direction of flow. (2) In a whole plant, because of a certain morphological structure, the nutrient channels are such as to carry food material to growing regions. A plant grows at both ends and so long as these are intact and growing, food flows toward them. If removed, food flows to other points and starts the growth of dormant short buds or root primordia. Once a stem or root has started growing Loeb's experiments show very clearly that the mass of growth formed is proportional to the mass of materials available.

Harvey considers that light is thrown on this problem by experiments of his own, designed to divide a plant into two parts physiologically but not morphologically. A jet of steam was directed against the stem of a young bean plant between cotyledons and first pair of leaves in order to kill the tissue throughout the stem in this region. In some plants the leaves and growing tip above this region wilt and die, but in many cases not only does no wilting occur but the tip continues to grow and *as rapidly or more rapidly* than control plants under the same conditions which are unsteamed. Nevertheless the *cotyledonary buds below the steamed region begin to grow and roots start to appear just above the steamed region.* If the air were sufficiently moist or the region surrounded by water there is no reason why these incipient roots should not grow out into a typical root system.

Harvey presents some of his results in a table which shows the data regarding the growth of "control" and steamed plants whose tops were not killed by the steaming. The average growth for the controls is 40.5 mm., and for the steamed plants, 59 mm. It is evident from the table also that the terminal bud has grown in the 24 hours immediately after steaming so that it cannot be said that the steaming causes even a temporary cessation of growth of the tip.

In discussing his results, it is certainly true, Harvey says, that sap must pass up the stem of these steamed plants, otherwise the tops would remain turgid and growth occur. Root inhibiting substances, if formed, must have passed upward along with the sap. Nevertheless we find roots developing above the steamed region despite the fact that the plant has a normal living root system below. The evidence is, therefore, conclusively against the existence of definite root inhibitive substances. If sap can pass upward in a steamed area we might expect that it could pass downward also. If inhibitive substances are formed by a growing stem these materials should reach the cotyledonary buds below. Nevertheless these buds develop. Since we cannot necessarily argue that because material can pass up a stem it must also pass down, the evidence points against the existence of shoot inhibitive substances, but is not unequivocal.

In a plant which has been steamed the nutrient channels are the same as in a normal plant. The apical bud is growing and attracting material to it so that we cannot say this food material is now available for the cotyledonary buds as we might say, had the growing tip been actually cut off or prevented from actively growing by a hydrogen atmosphere. The evidence is conclusively against the view that growing points prevent the growth of dormant buds by attracting and utilizing the nutrient material.

In conclusion Harvey says: "It would seem that the inhibitive influence must be dependent on living functioning protoplasmic connections. How are we to conceive of an influence of this sort without invoking a vitalistic explanation? I believe the explanation lies in the direction developed at length with the aid of metal models by Lillie.* Growing points are of a different electrical potential as compared with other points and the currents so generated passing through dormant buds in the proper direction, prevent their growth. The potentials are phase boundary or membrane potentials, possibly dependent on selective ionic permeability or solubility of two phases (cell and medium) to ions, and consequently dependent on normal permeability conditions throughout the plant. Interruption of living protoplasmic connections, then, means merely the interruption in continuity of semipermeable membranes in longitudinal axes of the plant (vascular bundles?) While we may be sure that the steamed portion of a plant will conduct an electrical current, since its normal semipermeable membranes have been destroyed there is no means of obtaining a return circuit. The plant is divided into two electrical systems instead of one and behaves practically as two distinct plants. As Lillie has suggested the effect of gravity on the inhibitive influence of growing stems, pointed out by Loeb, may be explained by movement of sap downward and passage of a greater current through this region because of increased electrical conductivity there. Biological polarity thus becomes electrical polarity and a given process at one region or pole is automatically accompanied by the reverse process at the opposite region or pole."

*Lillie, R. S. *Biol. Bull.* XXXIII, 135, 1917.

THE COMPARATIVE VALUE OF THE LABOR OF WORKMEN

THE brilliant French physiologist, Jules Amar, with whose important researches, especially regarding muscular activity, men of science have long been familiar, has recently been making a special study of the varying yield of workmen. Some years ago M. Amar made the important discovery that the consumption of oxygen is directly proportional to the muscular activity of an animal. This is significant from two points of view: It is of interest, on the one hand, to know the amount of oxygen absorbed by the body during any piece of work, whether useful work or some form of sport, and, on the other hand, it enables a physician or trainer to perceive in the graph recording the respiration, the degree of regularity or the disturbance of the latter.

Results of M. Amar's researches as given August 9th, 1920, to the French Academy of Sciences, can be briefly stated as follows:

1. When a workman performs a professional operation without overdoing himself, without excessive effort or accidental strain, his respiration is quite regular, both as regards the ventilation of the lungs and with respect to the appearance of the respiratory curves recorded.

2. The same operation performed by a number of workmen reveals differences in the amount of oxygen consumed which depend upon various factors, such as the degree of manual skill, the general good health and condition of the body, the facilities provided by the workshop, etc. Obviously factors such as these will vary according to the individual and to circumstances in general.

A very interesting point in this connection is, that the economy of respiration among apprentices increases in direct ratio with the amount of skill acquired.

3. Any awkwardness or clumsiness in the performance of the allotted task, as likewise any sort of malingering, whether the pretence of exerting extra force or as a simulation of weakness, is betrayed by disturbance of the air supply ventilation and by irregularities in the graphic record. These are so marked that it is impossible to mistake their source and thus a very easy method is at hand for the scientific foreman to check up soldiering" on the job.

4. Observations made upon athletes show that as a general thing they take a longer inspiration than usual and this encroaches upon the expiration. This fact proves that the organism makes a provision for itself at each respiration in excess of actual needs, thus storing up reserves for future demands.

This mechanism, which indeed certain athletes have practised intentionally, appears to be another example of those means of defence in which animal economy is so rich.

The general conclusion to be drawn from these experiments is that respiratory education is of the utmost importance both with respect to daily labor and to athletic sport, since it furnishes a means of providing the required oxygen for hematosis, *i.e.*, the arterialization of the blood in the lungs and for the vital changes which occur in the cell.

GROUP OF PATIENTS WAITING TO SEE THE DOCTOR IN THE CLINIC FOR ANIMALS AT BERLIN

A Clinic for Animals

Prescribing for and Operating upon Pets and Domestic Animals

WHILE in most cases wild animals appear to be practically free from disease since few of them live sufficiently long to experience the degenerative troubles of senescence, the animals which man has domesticated either as pets or for utilitarian purposes, are prey to almost as many ills of the flesh as he is himself. For this reason all of our agricultural colleges contain a department of veterinary medicine and surgery for the study of the diseases and injuries to which such animals are subject. Here and there, too, in our larger cities, are found hospitals for dogs and cats or for pet birds. But so far as we know Germany is the first country to establish a regular clinic, where animals of all sorts and suffering from the most various injuries and maladies can be taken for diagnosis of their ailment and advice as to the best method of curing them. As the accompanying pictures indicate the popularity of this institution is by no means confined to the humbler folk who patronize human clinics because of poverty. Here we see sitting side by side in the waiting room men and women of rank and fashion holding their suffering pets tenderly in their arms and bareheaded peasant women waiting to consult the wisdom of the doctor about the infirmities of their pigs and chickens, their horses and their kine.

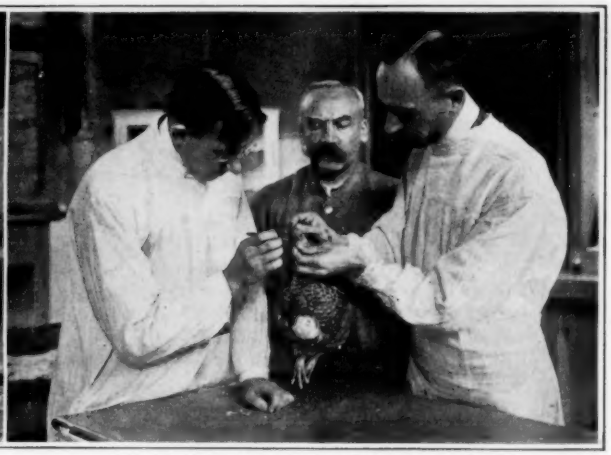
Here we may see a white-coated surgeon and his assistant gently placing a dark cap over the head of a dog, whose eyes have just been operated upon, while yonder some other suffering animal is being carefully bandaged. The owners of animals which can be successfully treated at their own homes receive careful instructions and take their property away with them. For those creatures whose condition is more serious and who require, therefore, expert attention and trained care, there is a hospital connected with the clinic, where they may stay until they are cured or well enough to complete their recovery at home.

In the third contingency that the animal's condition is found to be hopeless, the owner is summoned and gently advised that it is the part both of wisdom and of kindness to put the poor creature out of its misery, as the saying goes, rather than allow it to undergo weeks or months of uncomprehended agony or the discomforts of debility and decline. In such instances many are the pathetic scenes of farewell between a doting owner and a treasured friend and companion as of some beloved dog or favorite cat.

TWO WELL CARED FOR SUFFERERS

The advantages of such a clinic, particularly where accessible to a rural population, are strikingly evident. By prompt consultation of their experts a farmer may save not only a valuable individual animal, but may be enabled to prevent the spread of disease among his own herds and throughout the agricultural community. Again, just as the young physician derives invaluable training by the study of the thousand and one cases that come under his observation in a public clinic for men, women, and children, so the veterinary surgeon may

BANDAGING A BADLY MANGLED PATIENT



OPERATING ON A BAD CASE OF CANKER

secure a most useful working knowledge of the subjects of his future practice.

Such an institution may render important service to the community at large and, indeed, to the country in general, by the opportunities it affords for the discovery of incipient infections and the stamping of them out before they have a chance to sweep the country, destroying millions of dollars worth of property and even endangering, to some extent, the health of the populace, as in the cases of bovine tuberculosis, anthrax, glanders, foot and mouth disease, etc.

Finally, the personal observation of the good done by modern methods of the study and cure of disease would go far to check the ignorant superstition which still prevails among certain classes of people, to the effect that vivisection is merely senseless and useless practice of needless torture upon our humble and dependent friends. On the contrary, animals themselves have gained as much in relief from suffering and disease as have human beings through the information to whose door vivisection is the only key.

THE POWER OF HOLDING THE BREATH AS A TEST FOR LUNG CAPACITY

ONE of the valuable bits of information brought out by the tests for aviators made during the war, was the practical usefulness of the measurement of the time the breath could be held after taking a deep inspiration, for deciding the fitness of the subject to become an air pilot. This voluntary apnœa, as it is termed by physiologists, has been more recently studied by the French physician, Dr. L. Binet and Dr. Bourgeois, and the facts observed by them are worth the attention of schoolmasters, as well as of authorities upon hygiene.

When an adult person in normal health is asked to take a profound inspiration and then to hold his breath as long as possible, it is usually found that the average time during which he is capable of suspending respiration, varies from 40 to 50 seconds. When lying down this time can be extended, while when muscular exercise has been taken immediately before the time is considerably shortened. These studies of normal persons have now been extended to certain classes of invalids and we quote from some of the data observed from the *Presse Médicale* (Paris) of June 12, 1920, as abstracted in the *Revue Scientifique* (Paris), for October 9, 1920.

Patients suffering from chronic bronchitis or pulmonary emphysema are able to hold their breath, upon an average, not more than 21 seconds, while in tubercular patients this time is reduced to 14 seconds. Cardiac patients having a "compensated" lesion can hold the breath for about 34 seconds, while those whose affection is hypo-systolic in nature can do so for only 19 seconds.

The physicians mentioned stated it to be a general law that whenever there are disturbances of the respiration, due either to lung trouble or heart trouble, the period during which the breath can be held voluntarily is decreased in proportion to the gravity of the trouble. However, this decrease bears no relation to any diminution of the capacity of the lungs and some persons who are capable of inhaling a very large volume of air are, nevertheless, incapable of holding the breath for the normal period of time.

TESTING THE HEART AND LUNGS OF A DELICATE TOY SPANIEL

PUTTING ON A PROTECTIVE CAP AFTER AN OPERATION ON THE EYE

The Detection of Imitation Furs

How the Microscope Enables Us to Distinguish Real Furs from Spurious

By Leon Augustus Hausman, Ph.D.

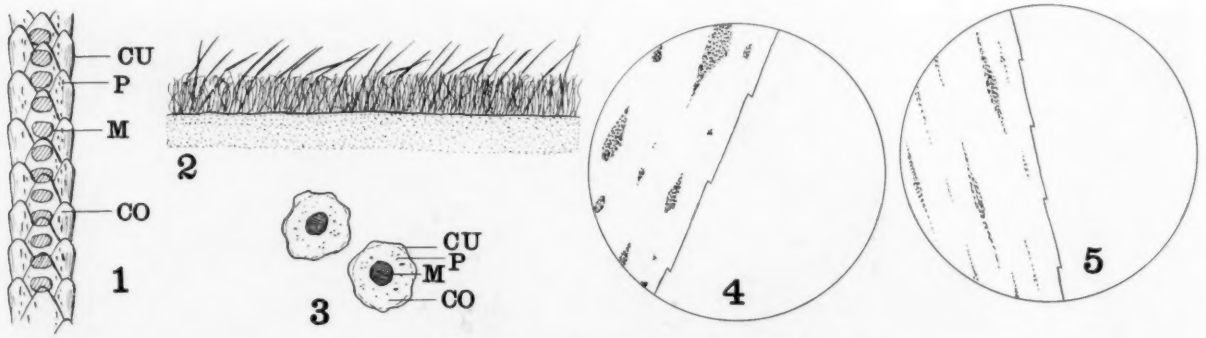
THE increase in the demand for furs during the past several years has been phenomenal. Not only, as formerly, are furs being made up into garments designed primarily for warmth during the winter, such as coats, scarfs, muffs, caps, and the like, but in addition are in ever-growing demand as articles of ornamentation at all seasons of the year. Furthermore the hair of many of the furred animals is employed in large quantities each year in the making of felts and similar fabrics. As a natural result, in the growth of the demand for furs, increasingly greater numbers of fur-bearing animals are, year after year, being killed, and at such a rate as to overbalance the natural tendency toward increase. Legislation designed to protect various species of valuable fur-bearers has been put into operation, but apparently the reduction still goes on. Certain mammals, once abundant, stand, today, in alarming proximity to extinction. And hence it is that many of the superior furs are becoming rarer and consequently progressively more expensive.

This growth in the rarity of certain furs has given rise to the ubiquitous attempts to furnish purchasers with imitations. the attempts have been legion, and considerable success has attended upon many of them. Sealskin, ermine, fox, bear, beaver, sable, chinchilla, otter, and others can be purchased at suspiciously reasonable prices, and seem to be suspiciously abundant. This is because it is now possible so to clip, dye, pull, and otherwise alter furs of certain types, that their original appearance is entirely lost, and that they may be sold under names not their own. Inferior furs, remodeled, may be sold under the names of furs much superior in wearing quality or in warmth, as for example when remodeled rabbit is sold for ermine or remodeled muskrat (perhaps the very one that you watched in an unremodeled state splashing about in your trout stream on your last fishing trip) is sold to you for your coat collar as seal of some sort or other at ten times its legitimate value, warmth and durability considered! The pelts of animals from warmer latitudes such as the opossum, marmot (woodchuck), raccoon, Manchurian dog, and certain species of monkeys are worked up and altered by skilful dressers into products very much different from their originals. The names which are given to such remodeled furs are usually the names of animals of colder latitude, which possess furs of quality superior to those of warmer zones in respect to suppleness and durability of skin, durability of the hair, denseness and softness of the under, or fur-hair, and fullness and length of the over or protective hair. Not only is there this natural difference between furs from animals of warm and cold latitudes, but another, an artificial difference exists as well. This is the difference produced by the dyeing and processing to which the warm latitude furs are subjected during the alteration process which often renders the individual hairs brittle and the whole fur less durable, in general, than it would have been in an unremodeled state. A comparison of the relative durability of furs with respect to their wearing qualities is very illuminating.

RELATIVE DURABILITY TABLE

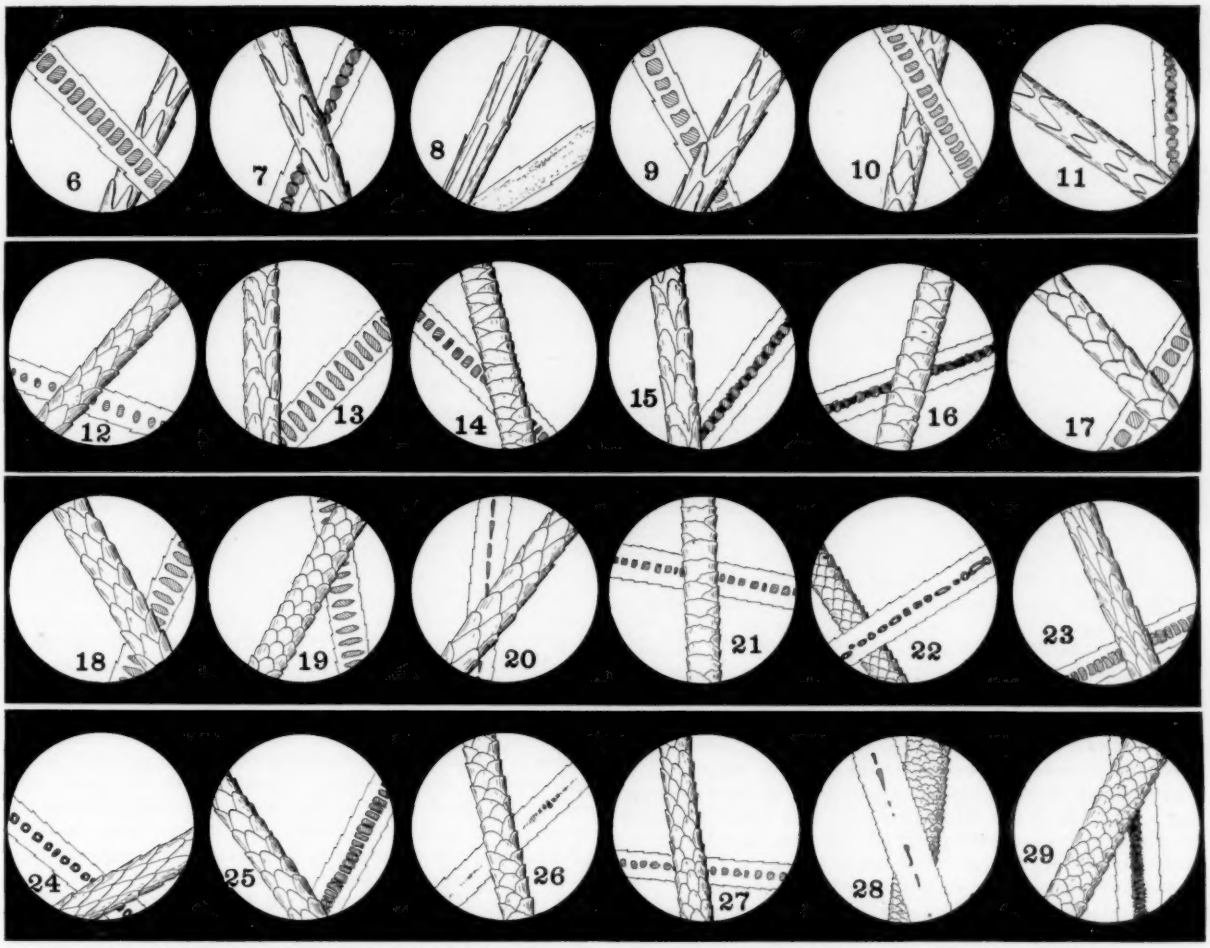
Vernacular, or common name of species	Relative durability Sea otter as standard, 100
Beaver	90
Bear, black or brown	94
Chinchilla	15
Ermine	25
Fox, natural	40
Fox, dyed	*20-25*
Goat	15
Hare	5
Kolinsky	25
Leopard	75
Lynx	25
Marten (Skunk)	70
Mink, natural	70
Mink, dyed	*35*
Mole	7
Muskrat	45
Nutria (Coypu rat), plucked	*25*
Otter, sea	100
Otter, inland	100
Opossum	37
Rabbit	5
Raccoon, natural	65
Raccoon, dyed	*50*
Sable	60
Seal, hair	80
Seal, fur	80
Squirrel, gray	20-25
Wolf	50
Wolverene	100

The above table by Peterson gives the relative durabilities of the furs when used with the fur outside, and not for linings. For comparison, the fur of the sea otter (*Latax lutris*), is assigned a standard of 100. In comparison with this table



FIGS. 1-5. THE STRUCTURE OF TYPICAL MAMMAL HAIR

Fig. 1. Typical mammal hair, showing the position and relationships of its structural elements. CU., cuticle, in the form of separate, imbricate scales; P., pigment granules; M., medulla, in the form of separate cells or chambers; CO., cortex. Fig. 2. Diagrammatic representation of the relationship of the fur to the protective hair, as it occurs in mammals. From the Duckbill, or Platypus (*Ornithorhynchus anatinus*). Fig. 3. Transverse sections through the fur hair of the Platypus to show the form of the medulla. Lettering as in Fig. 1. Figs. 4 and 5 show respectively, portions, very highly magnified, of the hair from the domestic cat, and brunette American to illustrate the way in which the pigment granule patterns in the cortex differ. Fig. 4 is typical of most of the fair-haired monkeys also. With higher magnifications differences also in the shape of the individual pigment granules themselves become appreciable.



FIGS. 6 TO 29. MICROSCOPIC APPEARANCE OF HAIRS OF SOME OF THE COMMON FUR-BEARING ANIMALS

consider now the one following, giving on the left the true names of certain furs and on the right the names under which these furs are often sold.

TABLE OF USUAL MISNOMERS IN FURS

The True Species	Altered and Sold as
American sable	Russian sable
Fitch, dyed	Sable
Goat, dyed	Bear, of various kinds
Hare, dyed	Sable or fox, of various kinds
Kid	Lamb
Woodchuck (Marmot), dyed	Mink, sable, marten (skunk) a very common misnomer
Mink, dyed	Sable
Muskrat, dyed	Mink, sable, very common
Muskrat, pulled and dyed	Seal, electric seal, etc., Red River Seal, Hudson Bay seal
Nutria (Copyu rat), pulled and dyed	Same as muskrat pulled and dyed
Nutria (Coypu rat), pulled, natural	Beaver, otter
Opossum, sheared and dyed	Beaver
Otter, pulled and dyed	Seal, of various kinds
Rabbit, dyed	Sable
Rabbit, sheared and dyed	Seal, electric seal, Hudson Bay seal. Red River seal, musquash (muskrat)
Rabbit, white	Ermine
Rabbit, white, dyed	Chinchilla
Kangaroo (wallaby), various species, dyed	Skunk (marten)
Hare, white	Fox
Goat, dyed	Leopard

The need of some certain criterion by which furs can be indubitably identified, as to species, is clear. In some recent publications dealing with the microscopic structure of the hair shaft from the zoölogical point of view, the author has pointed out that certain structural elements in the structure of the mammal hair are characteristic of species, and are of value in determining the species from which the hair was derived, Mammal hair, as a rule, consists of two very different sorts: (1) a short, rather dense, fine growth, called the under-hair, or fur-hair; and (2) a longer, coarser, stouter over-hair, or protective hair. Most species of mammals possess both types of hair (Fig. 2).

In both of these types of hair, the shaft is composed of four structural elements, distinguishable, after proper treatment, under the microscope, elements which no amount of dyeing or other processing, short of actual destruction of the hair as an article of value, can destroy. It is these minute and ultimate units of the structure of the hair which aid the microscopist in determining the species of mammal from which the hair was obtained. Fig. 1 shows a typical mammal hair shaft with the four structural elements indicated. These are: medulla, cortex, cuticle, and pigment granules.

The medula, or "pith" of the hair exists in various different forms, the chief major types, from which the variations seem to be derived, being: (1) the continuous (Figs. 29, 15 and 16), the fragmental (Figs. 26 and 28), and the discontinuous, or ball-like (remaining figures). This element is sometimes absent, or present only as minute vestiges of tissue scattered along the whole length of the shaft. Where but meager traces, like this exist in the hair a search near the mouth of the follicle in the skin—from which the hair grows—will usually reveal a portion of a fully formed medulla. The cortex element sur-

rounds the medulla, and usually forms the greater part of the hair. It is composed of many elongate, fusiform cells, coalesced together into an almost homogeneous, and usually hyaline mass. The component cells of the cortex can be dissociated and made to float about singly on the microscopic slide, and thus their forms determined. The cuticle, or outermost layer of the hair shaft, is made up of thin, transparent, scales, which overlap, like the shingles on a roof or scales on a fish. Of these scales, two main types are recognizable: (1) the imbricate discontinuous scales (Fig. 12), and the imbricate coronal scales (Fig. 11). The latter have been so named from the resemblance of each single scale to a crown or coronet. A glance at the figures will show that these two types of scales are subject to all sorts of intricate variations. The color of the hair is primarily due to a fourth element, the pigment granules. Although the pigment of the hair may sometimes exist as a diffuse color, distributed uniformly throughout the cortex element of the hair shaft, yet in the majority of species the pigment exists in the form of separate granules, scattered about among and within the fused cells of the cortex. These are scattered about, not apparently in "hit or miss" fashion, but are arranged in patterns of definite configuration in each species. Not only this, but the granules are characteristic also, in the color value and depth, shape, and size. They form, it is believed, a criterion, which, with further study, may prove to be of the greatest aid in specific determination. (Figs. 4 and 5). It is these microscopic elements in the structure of the hair whose forms, measurements in micra (1 micron equals approximately 1/25400 of an inch), and relationships constitute the series of determinative criteria to which reference has been made. No matter what may be done to the fur as a whole, short of actual destruction, these structures remain to indicate the origin of the pelt.

By glancing over the figures from 6 to 29 it will be evident that a series of known hairs in a collection can be arranged for microscopic examination and classified on the basis of the likenesses between various elements of structure. These can be filed away for comparison with unknown specimens.

The ordinary methods of preparation of hairs for microscopical examination have been discussed in the author's earlier papers and can be made readily after a little practice. Examination may be made, and is often necessary, of both the under- or fur-hair, and the protective, or over-hair. It sometimes proves helpful, also to prepare transverse, or cross-sections of the hair shafts. Several sections of this sort are shown in Fig. 3.

Figs. 6 to 29 show the microscopic appearance of hairs from some of the common fur-bearing animals. In each figure two hair shafts are shown, one treated to show the cuticular scales, the other to show the medulla. In identifying hairs the same portions of the hair shafts used for comparison must be taken. Since the character of the hair shaft elements differ in different portions of the shaft, several comparisons may thus be had as checks upon one another. The number of comparisons which may be had, thus insuring greater certainty in the value of the identification, will be appreciated when it is recalled that there are offered always two, and often four well-defined characters for comparison, and these in two different types of hair (over- and under-hair). Furthermore these characters may be compared in three different regions of the hair shaft, *i.e.*, the base of the hair (just above the mouth of the follicle), the middle portion of the shaft, and the region near the tip. Figures 6 to 29 were made from the middle portion of the hair shaft.

In taking measurements of hair shafts with the microscope great care must be exercised, and the average of a great number of measurements taken to guard against error. Size of the hair shaft itself, and size also of its various components, forms one of the valuable aids in determination.

It is reported that the remodeling and misnaming of furs reached such a pitch in England, that several years ago the London Chamber of Commerce forbade the further employment of misleading terms, and pointed out that offenders laid themselves open to prosecution under the ruling of the Merchandise Marks Act of 1887. Such legislation might have a salutary effect in countries other than England. Where scientifically accurate methods of determination of the specific status of furs can be made available it would seem that the standardization of furs might be, with advantage, brought about.

SILK FROM THE SLAUGHTER HOUSE

EVEN before the war German scientists were seriously investigating methods of extending the sources for obtaining raw materials from which to make artificial silk. Naturally enough the subject has recently engaged fresh attention and the remarkable statement is made in *La Nature* (Paris), May 22, 1920, that such a silk can be extracted from the flesh, *i.e.*, the muscles of animals—from that of horses and cattle especially. The raw material consists of the flesh of horses which have been killed because of accident and of that of cattle condemned by the Bureau of Health. Since this flesh is, naturally, very cheap the raw material is obtained at low cost.

The flesh is first macerated in a liquid designed to dissociate the muscular fibers by dissolving the substance which holds them together. These fibers have the form of short, limp filaments; they are next allowed to remain for some time in a second liquid whose action is analogous to that of tannin, giving the material greater tensile strength and imparting to it a silky character. The final product of this treatment consists of fibers having an average length of 5 cm.; these are somewhat harsh to the touch and in a measure resemble wild silk.

The non-fibrous part of the flesh which has not been dissolved is sold to manufacturers of glue. The principal industrial property of these fibers resides in the readiness with which, like silk, they can be rubberized and vulcanized. When placed in a bath of caoutchouc for two hours under a pressure of four atmospheres they become waterproofed just as silk does under the same conditions.

While the liquids employed in the treatment have been kept a secret by the inventor, he states that they are not at all costly and he estimates that a portion of the cost will be defrayed by the sale of the flesh which remains after the dissolving of the muscular fibers. The question of how to spin this artificial silk has also been studied and it seems the process of spinning used for carded wood is that which best suits this animal fiber.

A TEXTILE FIBER FROM THE HIBISCUS

THE mallow known to botanists as the *Hibiscus Cannabinus* is a handsome plant found growing over wide areas in the valley of the Niger River. It is called by the native the *Da* or *Da-dain*. It is not generally known that this ornamental plant produces an excellent fiber somewhat of the nature of jute. Indeed, it is sometimes called in India Madras jute. It has long been used by the inhabitants of the valley of the Niger for making the ropes with which they bind together their pirogues, as well as for fishing lines and harness for animals. Since the war, however, its uses have been extended and its production increased. While its filaments are rather short they are long enough to be manufactured like jute. Their color varies from gray to rusty white.

The seed yields a drying oil of a clear yellow color and the cake which is a by-product employed as cattle fodder. The plant requires a good deal of water for its proper development and is, therefore, sown at the beginning of the rainy season, so that it may attain full development before the dry season sets in.

In 1914 and 1915 in the ground belonging to the agronomic station at Koulikoro, upon earth subject to intermittent inundation, 6 tons of the cut and dried stalks, freed from seed pods, were obtained per hectare. These yielded 21.8 per cent of fiber.

PILE OF FRESHLY CUT RUBBER THROWN ON THE STREETS OF MANAOS FOR LACK OF OTHER SPACE, WAITING SEPARATION AND PACKING

Due to this practice the streets are very often filled with a bad odor

Brazil's White Gold*

Primitive Methods, Still in Vogue, of Collecting the Milk of the Rubber Tree

By William La Varre

GOLD in the Klondike and diamonds at Kimberly are strikes of fortune that will be immortal, but gems and minerals do not compose all of Nature's treasure. I wonder if there has ever been a period in which romance was so interwoven with overnight wealth, gaiety, and extravagance as it was during the rubber boom in Brazil. It had its beginning back in 1770 when Priestly discovered that Brazilian rubber, which the aborigines knew considerable about in the early days of exploration, was an excellent thing with which to erase pencil marks. After Macintosh had found a method of waterproofing garments with the substance, and Charles Goodyear had hit upon a method of combining rubber and sulphur, thereby hardening it, the gummy produce entered more and more into common use. The people of Brazil realized that this new industry of the commercial world relied directly on the white latex which flowed in millions of native trees. They found themselves in control of a great enterprise which required no extensive machinery, costly experiments, or risks: simply the bleeding of the wild trees and the hardening of the collected juice so that it could be shipped to the clamoring markets of the world where it would bring fancy prices.

Of all Brazilian towns Manaos, over 900 miles up the Amazon, and accessible by ocean-going vessels of 7,000 tons, felt the pulse beats of the new industry more keenly because it was in the center of things—the frontier gateway—through which the produce must pass to the outside world. She sprang up suddenly from a little sleepy village, where every one dreamed of better days but had done nothing toward attaining them, to a town of many thousands—a metropolis in which there was a seething mass of cosmopolitan life that came from everywhere and went to and from the interior, bringing several hundred thousand kilos of dirty looking balls of borracha weekly, the sale of which at 17 and 18 milreis a kilo would make the owners wealthy men. A milrei, or a thousand reis, was worth about 25 cents in American currency, which fixed the price of raw rubber at about $2 per pound in Manaos during the years of its highest value. Some of these men who made fortunes saved all they could get, and after accumulating quite a sum left the country; others spent their earnings in planting seringals. But a good part of the people squandered their earning from each voyage on the night of their arrival after the manner of the reckless of all conquests.

In Brazil rubber is known as borracha, and the people like, when lapsing into fond musings, to call it "o ouro branco"—the white gold. During 1906-7 it was worth 18 milreis per kilo. The milk was taken from wild trees by natives, especially along the Amazon, Madeira, and Negro Rivers and their tributaries, smoked into large balls weighing from 40 to 200 pounds, and sold to traders, who forwarded them to Manaos.

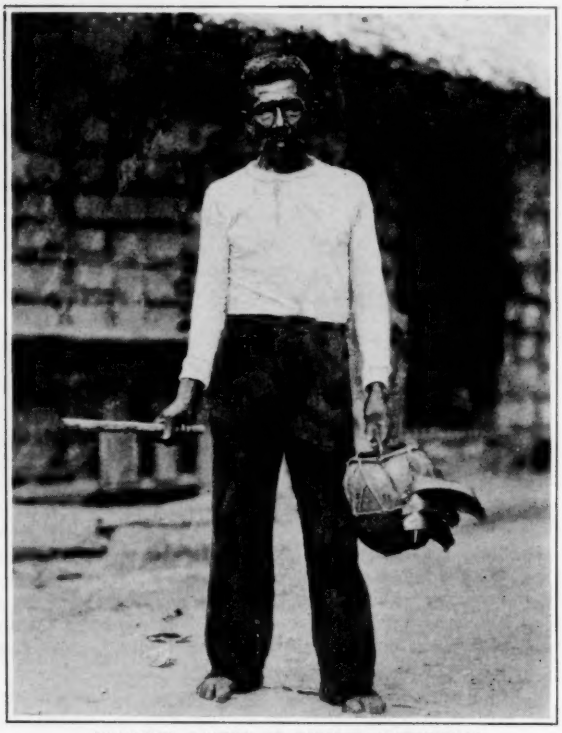
As in other sudden booms of wealth and fortunes, there came a slump in Brazilian rubber. One of the troubles was that people wanted to work for themselves, and would not work for others, or even band together into corporations of their own. Each native in the interior wanted to go out into the forest, find his own wild trees, bleed them, and smoke the rubber for himself. They preferred to work independently in this manner, laboring when they pleased, and how they pleased, even if they made only $1 a day.

The story of what happened to the goose that laid the golden egg is an old one, but fable makers of ancient days were wise old people. History repeats itself. Some of the natives decided that they might just as well cut the rubber trees down and take all the milk at once instead of drawing a gourd full a day for thirty seasons. So for several years, especially along the lower Amazon, they hacked away until, after several hundred thousand trees had been ruined, they realized that Nature cannot be hurried, however much in haste human nature may be. It was necessary to go easily and

* Abstracted from *The Pan American Union*, November, 1920, pp. 462-476.

slowly—a few well-placed and shallow cuts penetrating the bark only, will ooze the liquid gold for nearly half a century.

The labor question was the thing that turned the minds of certain promoters to new fields, with thoughts that perhaps there might be a possibility of transplanting those rubber trees to another country where labor would be very plentiful and cheap. The Brazilians took this idea with good-natured tolerance. "Well," they said, "it would not hurt to try, but Brazil is Brazil, and the trees that thrive in Brazil are not likely to live anywhere else." The British gathered a few shoots and carefully carried them into the East where they knew labor was to be had. Transplanted in Ceylon, India and other colonies, they seemed to thrive well, and more young trees were brought over and other plantations commenced. Then began the slumping of Brazilian rubber. It was discovered how cheaply rubber could be produced. Large com-



JOAQUIN, A TYPICAL RUBBER GATHERER
Note the small hatchet for gashing trees and the gourd bucket with the attached leaf cups

panies became interested, and it was not many years before they were receiving nearly all of their raw material from west of the Pacific and from plantations of their own. The amazed Brazilians saw their rubber fall in value from 18 milreis to 4 milreis per kilo, and they began to mood and dream again. Some few started cultivating rubber in Brazil, but as yet it is small business in comparison with the Eastern holdings where labor can be had in abundance. Today Brazil no longer controls the rubber industry.

In 1919 I found myself nearly a thousand miles up the Rio Negro, in the midst of many poor natives who are managing to make a meager existence from smoking the few gallons of milk they are able to collect each day during the few months that the wild trees will profitably bleed their latex.

It was at Cucuhy, frontier outpost of the Brazilian Government on the Rio Negro, that I had the best opportunity of observing the natives—the "little men" in the rubber industry—at their work. The place was very lonely, and to pass the time I used to spend whole days in the forest with the collectors. Of them all I remember more especially old Joaquin da Silva, a little wrinkled Caboklo, or half-breed. He lived with his wife, a son of about 30 years, and two young children, in a little thatched hut beside a twisting egarupe that flowed into the Negro from the east.

One evening old Joaquin was squatting down in one of the thatched huts where I lived on the banks of the Rio Negro. He was telling me of the hard time he was having to collect enough rubber to provide himself with the necessary requisites of life as he knew it.

"It is very bad, senhor," he said, "my trees do not give as much milk as they used to, and I have to walk farther and farther to get 4 quarts of white *leite*. I am growing old, and soon I will not be able to walk so far; what shall I do then?"

I did not answer him, because I did not know what to say. After a while of thoughtful silence I said: "Joaquin, will you take me with you into the forest so that I may watch you get the milk?"

"Certainly, senhor," he replied in his soft, lisping tongue. "If it does not rain, I will come for you at 6 of the morning—if it rains as it did this morning, there will be no use in going, for the milk will be ruined again."

At 6 the next morning I was dressed and waiting for Joaquin. With customary readiness he arrived at 7 and we started off together up the meandering egarupe in his little dug-out canoe. It was an ancient craft, barely large enough for two, and there was but an inch of freeboard when we had taken our places. Joaquin sat in the bow, with his blunt feet extended out over the water ahead of us, and paddled with short, quick strokes against the current. When shallow places were reached he stood up and poled, causing me to hold my breath for fear the next motion would cause the canoe to overturn.

At a bend in the stream, where granitic rocks outcropped, we paused while Joaquin got out and fetched a small gourd bucket, leaf cups, narrow-bladed hatchet, and a bow and several fish arrows from his home, which was hidden from view behind the light green leaves of banana palms.

We continued up the ever twisting and narrowing creek for an hour to another clearing in which there was a tumbled-down shack. Here we left the canoe and, picking up our equipment, we took to a small trail that led into the forest. Joaquin picked up a handful of soft clay which he placed in the gourd bucket, and gave me a bundle of long, slender, and very light rods of pith to carry, which had been lying over a fallen log to dry in the sun. We soon had left the warmth of the sunshine behind and were journeying through the dark dampness of the jungle.

Presently Joaquin stopped at the base of a tree around which a space had been cleared of undergrowth. The tree was perhaps a foot in diameter and rose straight upward for 20 feet before it branched. The bark was somewhat furrowed and mottled with green, brown and gray tones. The leaves grew in clusters somewhat like our hickory, only larger.

Joaquin laid his tools upon the ground, and took one of the slender pith rods from me. Holding an end of the rod in each hand, he stooped down near the base of the tree, and encircled it with his arms. The pliable rod bent around the bark, and the old man overlapped the ends on the far side nearly a foot higher up the tree than the middle which faced him. He drove wooden spikes, cut from palm midribs, through the overlapped ends, and through the pithy rod into the bark at intervals of 5 inches, thus securing the improvised band to the tree. From the gourd bucket he took some of the white clay, and with it puttied up the seam between the band and the bark of the tree, forming thus a smooth trough which encircled the tree at an angle with the horizontal of about 45 degrees. He replaced the unused clay in the bucket, and picking up the small-bladed hatchet cut 1-inch gashes, one directly over the other in the bark above the trough. These cuts were carefully placed and did not penetrate the wood of the tree. No sooner had this been accomplished than a thick

white juice commenced to ooze from the cuts, trickle down over the bark, to drop finally into the smooth inclined trough, and run down it to the lowest part. Joaquin quickly spiked a small leaf cup below the lower point, just as a tiny bead of white liquid fell. Other drops followed. The old man had been very skilful in his operations, hardly losing a moment. The whole task had been accomplished in three minutes.

PITH BAND SPIKED TO THE RUBBER TREE AND THE LEAF CUP BELOW CATCHING THE DRIP

We took up our tools and moved on to stop later at another tree, larger than the first, which already had a band around it and showed by the swollen and scarred trunk that it had been cut for many years. It took Joaquin but a moment to fasten a cup below the dripping point and cut fresh gashes in the bark above. Then we moved on. The next tree had a band and a cup half full of watery milk which had been diluted by the rain of the previous day. The cup was emptied on the ground and refixed to the tree. Fresh gashes were cut, and we moved on again.

During the morning we passed 105 trees, most of which had bands already in place, and some of which had cups attached. Others which had not been previously bled had nothing. Whatever was lacking was attended to.

It seemed that everything that Joaquin needed in his business could be had in the surrounding forest. When a certain thing gave out he needed but to pause, look around into the forest growth, choose a certain specie of plant or tree, and go and get the material from which he could fashion the necessary article. The bucket which he carried was a good example. It was made by slicing off the top of a large *cuia* fruit about 10 inches in diameter, scooping out the inside, and binding strips of *tucum*, a fiber made from a palm leaf, about it, drawing the ends up over the top and tying them into a handle.

When we had come to the end of the trail, we paused to rest beside a cool, clear brook. After half an hour or so, we stretched our limbs, picked up the gourd bucket and small hatchet, and started back over the trail.

As we passed each rubber tree Joaquin with hardly a pause emptied the collected milk from the leaf cups, replaced them, and was on to the next tree. As we drew nearer the trees which we had first visited on our journey into the forest, the cups became fuller and fuller, until, finally, the last tree had a cup that overflowed. The pail by that time was full of thick white milk—1 gallon of liquid rubber.

When we arrived at the egarupe, Joaquin took off his clothes and plunged into the water to cleanse and cool himself. Then we poled down the stream, drifting sometimes, listening to noises, and talking. I stuck my finger into the white liquid, and held it into the sunlight for a moment. The coating turned yellow and hardened, until I was able to peel it off as though it had been the finger of a rubber glove, and it was elastic.

"When do you cut the trees again—to-morrow?" I asked my companion as we came in sight of his clearing.

"No, senhor, it is not necessary to cut them again until day after tomorrow. You see it is this way: On the first day the milk does not run very well, and we only get 1 gallon of milk. Tomorrow we will get more, perhaps 6 quarts, because on the second day the milk runs better. But on the third day it must be cut again."

"And how many years can you take milk from a tree?" I asked.

"That depends, senhor. I am very careful, and have been cutting some of the trees for 12 seasons. I begin at the bottom; the first season uses up about a foot of the trunk near the base. The next season I begin a foot higher, and so on. After several years the band is so high up the tree that I have to build a scaffolding to reach it; then I begin at the bottom again.

The little canoe slid up on the bank, and we got out. Joaquin carried the bucket, and I followed him over the narrow trail that twisted in and out between banana palms. We came to a mud hut with a palm-thatched roof, and the old man stepped graciously aside and with a wave of his hand bade me enter and make myself at home.

After a meal of pineapples, bananas and coffee, Joaquin took up a bucket of latex that his wife had brought in, and with his own full gourd led the way to the edge of the forest, while his son, Joan, and I followed. In a few strides we came to a small clearing, where the ground was covered with ashes. There was a shallow hole in the center of the clearing, and beside it lay a large metal pan.

Joan went into the surrounding woods and returned shortly with an armful of short lengths of reddish wood, while Joaquin

BALL OF RUBBER REVOLVING IN SMOKE FROM THE CONICAL FLUE

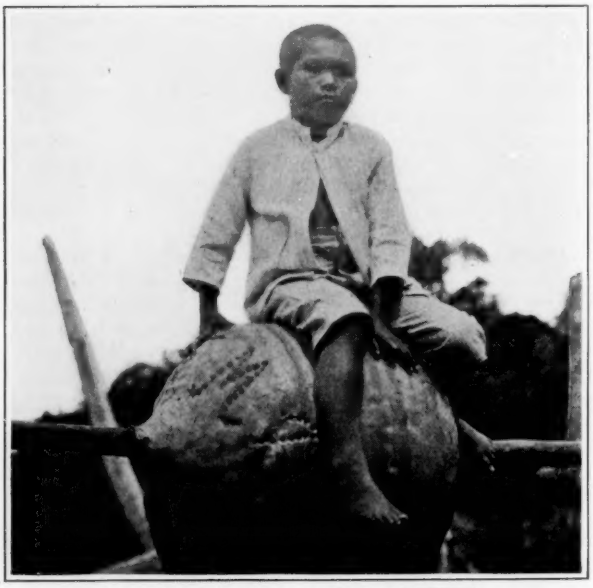
The milk coating turns yellow and hardens almost immediately. It then goes over the pan for a new coating

made a small conical-shaped fire in the hole. The wood split easily into pieces and was laid against the fire upright. Over this was placed a conical hood of iron, the apex of which had been truncated, and a round piece cut out of the edge of the larger circular base. This hid the fire from view. Air, entering through the cut in the bottom, blew the flames within the

hood and sent a column of heavy smoke up through the small opening in the top.

The metal dish was held over this smoke for a few moments, bottom upward, and a skim which had formed around the inside from the residue of previously contained rubber latex was torn off. It had the feel of a thin sheet of rubber almost as it is sold in the stores. Then the newly collected milk was poured into the pan and the vessel was shoved up close to the smoking flue. Joaquin squatted down beside the tub of milk and dipped the smooth flat blade of a paddle into the liquid, coating it completely white. He removed it from the milk and held it, after allowing it to drip for a moment, in the smoke, turning it over and over so that all sides would be evenly touched by the smoke. The white coating gradually began to turn a creamy color and to harden. The paddle blade was dipped into the fresh milk again and recoated with liquid. Again it was held in the smoke, and again as the acid in the smoke touched the alkaline latex it coagulated it into a dry, elastic coating. These operations were repeated many times until there was a quarter of an inch coating over the blade.

With a sharp knife Joaquin then cut half way around



A FINISHED BALL OF CRUDE RUBBER

the paddle edge, and ripped the covering from the blade. This he spread out like a mat and rolled it around the center of a short, strong pole, and made it secure with strands of tucun fiber. Then this wrapping was held over the pan of milk, Joaquin holding one end of the pole and his son grasping the other on the opposite side of the pan of milk. Joaquin scooped up a gourdful of milk and poured it over the wrapping, coating it white. Then they moved the pole over the smoke and hardened the thin covering of juice. Then it went back over the pan, and a new coating was added, and again the smoke was allowed to harden it. This process was repeated for over an hour, and gradually the mass in the center of the pole enlarged and took the shape of a large ball, which grew larger and heavier with the addition of more milk, and contact with the acidic smoke.

"From a gallon of milk 2 kilos of rubber can be made," Joaquin told me. "Today we will make about 4 kilos from all the milk. In 1906 we got 15 milreis for each kilo; now the Portuguese pays us only 2."

A week later a trader in a blue batalao poled and paddled his way up the river and announced himself on a loud-sounding sea shell. Joaquin and his son came over shortly with a small ball of rubber weighing 10 kilos.

"Twenty-five milreis!" said the trader, "What do you want?"

"Money only," replied Joaquin.

"Money only?" questioned the Portuguese, as though he did not like the idea at all, and he did not, because he would be cutting his profits in half. "Don't you want something else? I can only let you have 10 milreis in money; you'll have to take the rest in goods."

Joaquin bought three yards of cheap calico, stiffened with flour, a small box of tobacco, a box of matches, and each of them took a drink of *caxasa*. Usually they take a good part of their pay in *caxasa*, a watery looking drink made from cane juice that is so strong that, to quote the familiar expression, one uses alcohol to dilute it.

As it took them three days to make that much rubber, which brought 10 milreis, 3 yards of cheap cloth, a 5-cent box of matches, with 25 cents worth of *caxasa*, one has to pause a moment to reckon how many days they would have to work to buy a pair of shoes—but fortunately Joaquin doesn't wear shoes.

This old man, his son, and his woman are but three of many hundreds of poor natives who are working during five months of the year, November to March, seeking out the wild trees and taking their milk. They represent the one-man way of producing rubber, and they are, in a way, typical examples of the one-man way of doing anything in these days of highly concentrated industry. From them and their very crude methods grade the wealthier and better equipped gatherers, men who are able to employ a few helpers—from Indian tribes mostly—and the larger company holdings, where trees are cultivated and bled by highly paid labor. But compared with eastern development these are all mere infantile industries.

When I returned from the interior I found the people of Manaos very elated. "What is the matter?" I asked a friend whom I met on the street.

"Oh, senhor, have you not heard?" he asked, joyfully hugging me and patting my back after the custom of the country. "The cable reports that there is an insect that is killing all the rubber trees in the East, and soon there will be none left in Java, Siam or India—isn't that good news, senhor?"

If it were true, I'd say it was good news—for Brazil.

But leaving aside all questions of plagues, and of waiting for some kind power to kill the rubber trees everywhere except in Brazil, the word I have to give my friends in Brazil is: "Wake up." Unless they are to relinquish all control in one of the greatest industries of the world, they will have to cultivate extensively the *hevea braziliensis*, that noble tree which thrives best in its native land, but which can be made to yield profitably in other climes if the commercial needs of a quickly moving civilization demand more material than Brazil is able to supply.

DYER'S FORMULA CARD

THE National Aniline and Chemical Company has issued a very useful pamphlet which will aid the dyer regardless of his special field in producing the season's shades. The particular dyes recommended in each case have been selected with the object of obtaining the best results in the various materials which are offered for dyeing.

The following summary shows the field covered by the publication:

1. Dyeing on Silk with Acid Dyes.
2. Dyeing on Cotton.
   - (a) With Direct Dyes.
   - (b) With Basic Dyes.
   - (c) With Direct Dyes Topped with Basic Dyes.
3. Dyeing on Woolens or Worsteds with Acid Dyes.
4. Chrome Colors on Woolens; Top-Chrome Method.
5. Dyeing on Leather.
   - (a) On Chrome Tanned Calf Skin Sumac Bottom.
   - (b) On Vegetable-Tanned Sheep Skin.

SPECIMEN OF NEREOCYSTIS FROM ALASKA. NOTICE LENGTH OF PLANT
(Photo by courtesy of Professor Rigg, Univ. of Washington.)

Indian Uses of Kelp

Fishing Lines, Bottles, Toys etc., Made from Seaweed

By J. C. Leachman

SEAWEEDS have been employed in many parts of the world and for many different purposes. In Japan they have become the basis of an important industry, being used for many different technological purposes and for food. The inhabitants of Norway, Denmark, Scotland, Ireland, France, Tasmania, China, and Formosa are only a few of the many peoples who have made use of algæ as a source of food and many other things. The prominence of kelp as a source of potash for European nations during the recent war must not be overlooked. Perhaps nowhere, however, have seaweeds been put to such diverse uses as among the Indian tribes of the North Pacific Coast.

Several Indians in the Puget Sound district have been questioned, but none of those now living seem to have used kelp or any other seaweed themselves. All informants had however heard of its use by other Indians in the old days. Only one object made of kelp has been seen by the present writer, a fishing line in the University of Washington State Museum, and this specimen is very dry and brittle. The temporary nature of the utensils for which seaweeds were used, the ease with which new supplies were obtained, and the perishable nature of the material would all account for the comparative rarity of museum specimens.

Several varieties appear to have been in common use, among them: Macrocystis pyrifera, Nereocystis leutkeana, Pelagophycus porra, Porphyra laciniata, Rhodymenia palmata and Ulva latissima. The first three of these are commonly lumped as kelp. This word was originally applied to the slag resulting from the burning of heaps of Fucus and other seaweeds for the purpose of obtaining potash, iodine and other chemicals. Later the term kelp came to be applied to various large seaweeds, usually brown in color, which form a very conspicuous item among the jetsam remaining on the beach after the tide has gone down. It is worthy of note in passing that the origin of the word kelp is not known.

Macrocystis pyrifera, also known as black kelp or devil's apron, is found from Magdalena Bay, Mexico, to Sitka, Alaska. It is found as a rule associated with Nereocystis leutkeana, but growing in deeper water. It often attains a great length and plants measuring as much as 1,000 feet have been reported. It usually grows in water which is from eight to fourteen fathoms deep and in common with other varieties of kelp, requires a rocky bottom as well as considerable and continuous movement of the water. It is anchored to the bottom by an immense holdfast, which often exceeds three feet in diameter, and from which extend a number of stipes or stems, which are seldom more than half an inch thick and are frequently fifty feet long. At intervals of less than a foot along these stipes grow small oval bladders or pneumatocysts from each of which springs a leaf-shaped frond about two feet long and four inches wide. The plant appears to be a perennial and grows from spores which ripen at some distance below the surface. It does not seem to have been used by the Indians as much as some of the other species, probably on account of the numerous offshoots from the stipe which rendered it less serviceable.

Nereocystis leutkeana is known as brown kelp, bladder-kelp and sea-otter's cabbage. It was used far more than any of the other seaweeds and is the species usually referred to when kelp is mentioned. It closely resembles Macrocystis pyrifera in type, except that there is only one stipe springing out of the holdfast. This is hollow for a third of its length, a feature wherein the greater part of its usefulness lay. The stipe is terminated by a pneumatocyst about five inches in diameter and separated by a slight constriction. From the bulb branch out numerous fronds, narrow but often of great length. In a specimen of average growth the first forty feet of the stipe will be solid, while the remaining hollow portion or apophysis attains a length of about twenty feet. The plant is an annual and grows from spores which in the Puget Sound district are ripe about the middle of May. It requires the same conditions for growth as Macrocystis pyrifera, that

FULL-GROWN PLANT OF ALARIS FISTULOSA
(Photo by courtesy of Professor Rigg)

is to say, a rocky bottom to afford anchorage for the holdfasts and enough movement of the water to bring the requisite quantity of nutritive chemicals within its reach. The distribution of the plant is wide, reaching from a little south of Point Conception, California, to the Arctic and to the shores of Kamchatka.

Pelagophycus porra, known also as elk-kelp, sea-pumpkin or sea-orange, was formerly known as Nereocystis gigantea. Its distribution seems to be more limited than is the case with the other kelps. It is said to occur not much more than a hundred miles north of San Diego Bay, in California, and extends from this point southward. It closely resembles Nereocystis leutkeana in every respect except that the pneumatocyst is larger, sometimes twice or three times as large, and from it spring horn-like, frond-bearing stipes, from which fact it gets its name of elk-kelp. It appears also that a larger proportion of the stipe is hollow than is the case in Nereocystis.

Porphyra laciniata, or purple laver, was used by the Indians in conjunction with the green and red lavers. It is occasionally gathered by the Chinese resident on the Pacific coast for food. It grows between tide marks on rocks and stones, the fronds, which spring from a common holdfast, resembling delicate ribbons. Rhodymenia palmata (or dulse), the red laver and the green laver, Ulva latissima are also used by the Indians. They resemble the purple laver on superficial examination in all respects but color.

The use of seaweed for food seems to have been a common practice in many parts of the world. It is still so used in Ireland and Scotland and, more seldom, in England, while Japan bases a large industry on the gathering and preparation of various seaweed products such as kanten, kombu, wakame and various forms of nori, the latter being the generic name for seaweeds. China, Hawaii and many other districts in the Pacific Ocean also give it a place in their dietary and in this regard the Indians of the North Pacific Coast were not exceptional. The Indians in California, especially those living a few miles inland, made periodical excursions to the beach to gather seaweed and searched especially for the large stems and bulbs of kelp. It is probable that the salt was one of the things sought. That this was not the only reason appears from the fact that the Indians of Fort Ross, California, formerly gathered large quantities of kelp from the beach and used it in making a soup which they prized highly. Swan states that dulse, while not in common use, was an article of diet among the Haida Indians of Queen Charlotte Islands and other tribes. Bancroft mentions that seaweeds were prepared for use in winter; this was probably done in the manner described by Swan, who says that green and purple laver and dulse are compressed into blocks and sliced up with a sharp knife as needed. Bancroft also says that some varieties, such as eel-grass, were eaten raw. Reference has already been made to the salt obtained by the Fort Ross Indians in California from algæ. A more direct method of securing this substance was that employed by the Indians of the San Juan Islands, north of Puget Sound. The fronds of the kelp were laid on clean drift logs and exposed to the sun, with the result that efflorescence of the salt occurred which was then easily collected and stored in suitable receptacles.

More or less closely connected with the subject of food is that of drink and here also the kelp proved of use. Rigg states that the apophysis is used as a "worm" in the preparation of "hoochena," a drink popular among the Eskimos. Stone-cooking was a method very generally employed in this culture area, and we are informed by Swan that seaweed, probably of the laver species, was used to prevent direct contact of the hot stones with the food. Fern leaves were also used for this purpose.

In connection with the use of seaweed for food, it should be noted that it has been used in Europe as an emergency ration for cattle, sheep and horses, and that deer have been seen eating it in times of scarcity. The natives of Kodiak Island, South Alaska, also used seaweed for feeding cattle, particularly afte rthe Katmai eruption had destroyed most of the pasturage.

Perhaps the use of kelp which involved the least preparation was its employment as bait. A section of the stem was weighted with a stone and let down to the bottom of the water with a line and buoy attached. This was allowed to remain for some hours and was then gently drawn up into the canoe. If the fisherman were fortunate he would find a sea-urchin feeding on the kelp. These animals are still used for food by various Indian tribes, but not in such large quantities as formerly. Another use which involved no more elaborate preparation than the severing of the bulb from the stem, was that in which the bulb served the purpose of a bait-holder, keeping the bait cool and moist. A similar utensil was used as a bottle for carrying water on fishing expeditions. The use of the bulb as a bottle seems to have been fairly widespread; they were used in South America and Tasmania as water-bottles, while in New Zealand the pods of a large seaweed were used by the natives to store whale-oil which they used in the lamps in their sleeping-rooms. These, when filled, held about a quart of oil each, were tied at the neck with flax fiber and resembled in appearance a bottle made of rubber. They are still used in the Puget Sound district to contain fish-oil, used both as a sauce and for preserving fishing tackle.

Kelp also played its part when the canoes were overtaken by rough weather. It was, and for that matter still is, a common practice to tie the canoe to a number of growing kelp plants and let her ride there till the storm abates. Among the Eskimos the apophysis is used as a siphon for emptying the water out of their kayaks, which, being decked in, are not readily baled out in the ordinary manner.

It is well known to the people of the North Pacific Coast area that many kinds of wood can be readily worked into desired forms after being heated in a fire or steamed. An ingenious process involving this fact is employed by the Makahs at Cape Flattery. In making halibut hooks, knots of hemlock are first shaped with a knife and then inserted into a hollow piece of the stem of the kelp and roasted or steamed until they are pliable.

The use of kelp for fishing lines on the Northwest Coast is frequently referred to in the literature and seems to have been spread from the coast of California to that of Alaska. It was stated by MacMillan in 1899 that such lines are still preserved as curiosities by a few native fisherwomen. Swan's account of the manufacture of these lines, which are principally used for taking halibut, deserves to be quoted in full:

"Fishing lines are made of the kelp-stem. This is collected by two sticks joined together like the letter A. At the bottom a stone is secured as a sinker; five or six inches above the stone a knife-blade is fastened between the two sticks and a line is then fastened to the upper end. This instrument is slipped over a bulb of kelp, lowered to the bottom and a slight pull severs the stem close to the ground. They usually prefer the kelp growing in ten or twelve fathoms of water; most of the stems, however, that they procure rarely exceed ten fathoms in length and many are not over five. For more than half its length the stem is hollow, but this section is not taken for lines. When a sufficient number of stems have been cut they are placed in fresh water—a running brook being always preferred—where they remain for five or six days, or until they have become bleached nearly white. Then they are partially dried in the smoke and knotted together at the ends, and further dried in the sun, after being stretched to their full length and their utmost tension. This reduces their size to that of a cod line. They require several days' exposure to the sun and air before they are sufficiently cured. They are taken in every night while curing and are coiled very neatly each time. When perfectly dry they are brittle, but, when wet, they are exceedingly strong, fully equal to the best cod lines. The usual length is from eighty to one hundred fathoms, although it is seldom that fishing is attempted at that depth, except for 'be-sho-we,' the black cod; and the probable reason for their being so long is to guard against accidents by which a portion of the line may be lost. When fishing in shoal water it is usual to tie a portion of the line at the required depth and lay the remainder on one side, so as not to endanger its being entangled by any fish that may be caught. Lines for small fish are made from kelp stems of the first year's growth which are about as large as pipe stems." It is interesting to note that fishing lines made of Chorda filum were used in Scotland until quite recently.

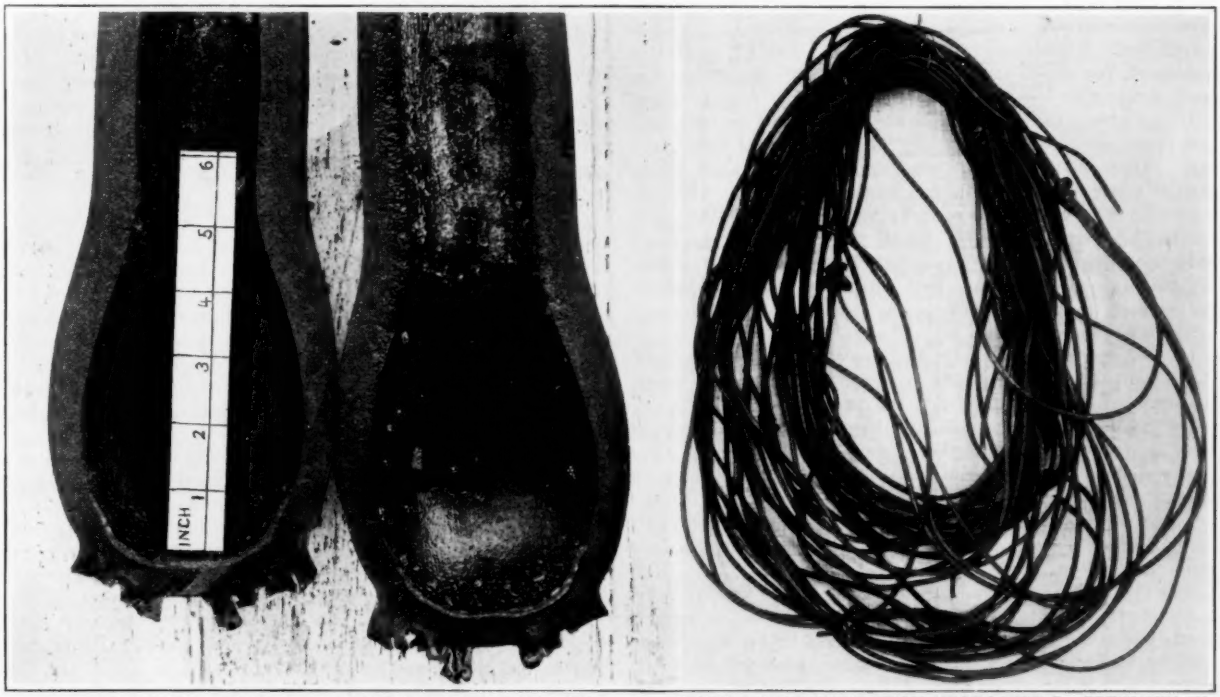
Seaweed is also used in the construction of houses, where it is employed in "chinking" the cracks in boards and the interstices between logs. This would probably be a use confined to the smaller species, some of which when dry make a sort of natural excelsior packing. The eel-grass which is often found washed up on the shore was used to produce the white parts of the pattern in basketry and is still so used to a limited extent by the Indians at Cape Flattery. It is bleached in the sun before being woven into the baskets.

Toys were also made from kelp, the children using sections of the stem to make the wheels of toy wagons. It was also used by the boys in a game in which they imitated the killing of a whale, towing a long kelp-stem along the beach and darting harpoons into it until it was split or the supply of harpoons exhausted.

Kelp and other seaweeds have been used from time immemorial as fertilizers and it is noteworthy that the time for gathering seaweeds that have been cast up on the beach is regarded as a festal occasion in France, Scandinavia and the New England Coast of the United States. The natives of Kodiak Island invariably use Nereocystis and Alaria fistulosa as fertilizers for their gardens, but it is practically certain that this use was not known till the introduction of vegetables by the whites.

Kelp seems to have had its uses in medicine also. The Indians at Sitka use the hollow portion of the kelp to cure headache. The smaller end is placed in the ear and the other against a hot stone, which results in the production of steam from the water in the kelp. At Neah Bay, among the Makahs, portions of the bulb are used by nursing mothers as a poultice for caked breasts and it is said to be soothing and antiseptic. The apophysis is also used according to one informant of the writer's to give an enema of oil. It should be noted that agar agar, which is of so much importance to the modern medicine man, is a seaweed product, being made from the genus Gelidium.

Seaweeds were used in several ways in ceremonials. Amulets were in constant use and one of the most powerful of



SECTION OF BULB OF NEREOCYSTIS SHOWING ITS UTILITY AS A BOTTLE
(Photo by Professor Rigg)

FISHING LINE MADE FROM NEREOCYSTIS. SPECIMEN IN UNIVERSITY OF WASHINGTON STATE MUSEUM
(Photo by the author)

these was a belt of seaweed tied in magic knots. No information seems to be available as to the kind of seaweed used for this purpose or the type of knots, but it seems probable that kelp would be used as few other species would be suitable. On war expeditions it was customary to wear the hair tied in a knot at the back of the head and into this knot were thrust sprigs of evergreens, but on ceremonial occasions the evergreens were replaced by wreaths of cedar bark or seaweed. It may be mentioned here that seaweed has ceremonial uses in Japan also and that kombu, a food made from seaweed, is said to be a symbol of a gift.

One of the most ingenious schemes of all was that in which a shaman convinced the beholders that he was able to speak with a spirit which inhabits fire. For this purpose a shallow trench was dug in secret from the fire, either to the outside of the house, or if the proceedings were to be out-of-doors, to a convenient rock or bush. The hollow portion of a kelp stem was buried in this trench, which was then carefully filled in and all traces of it obliterated. A confederate was thus enabled to keep up a telephonic conversation with the operating shaman, while the effect on the astonished onlookers may be readily imagined.

It is quite probable that there are some uses to which kelp and other algæ were put that have now been forgotten, but it seems safe to say that there is no other single material, with the exception of cedar, which was put to such a large variety of uses or filled a position of such great economic importance with these people.

The Ionic Dissociation Theory

Some Interesting Experiments for the Amateur Chemist

By Albert T. Fellows

MOST lovers of chemistry are familiar in an offhand manner with the Ionic Dissociation Theory; but very few thoroughly understand this theory. This situation is really to be deplored, for this theory is such a potent weapon in the hands of either the chemistry pupil or the eminent chemist. The purpose of this paper therefore is to familiarize the student with this theory; not by giving the theory alone and having him memorize it, but by teaching it in the language of Nature—by experiment.

First of all, it seems advisable to give the elementary principles of the theory before studying the details and performing the experiments. The principle points of the theory follow.

I. Arrhenius, in 1887, was led by various phenomena to advance the theory that some compounds break up or dissociate when dissolved in water. A portion, at least, of its molecules break up into two parts. One of these is charged with positive, the other with negative electricity. These charged particles are known as positive and negative ions.

As an example, when we put salt (NaCl) into water, dissolve it as we say, it disappears. The first part of our theory tells us that a certain number of the salt molecules are broken up or ionized into ions of $Na^{\bullet}$ and Cl'. The ($^{\bullet}$) indicates a positive, the stroke ($'$) a negative charge of electricity. Unless our solutions are very dilute, they will contain along with the ions the substance in molecular form. Then our solution really contains the following, NaCl, $Na^{\bullet}$, Cl', H_2O, $H^{\bullet}$, and OH'. That is the water is also slightly ionized, and if the ions of water are present in sufficient quantity, they will combine with $Na^{\bullet}$, and Cl' to form hydrochloric acid ($H'Cl$) and sodium hydroxide (NaOH). These last two substances are only theoretically present since in the extreme dilution they remain dissociated. Please notice that the ion differs from the atom in that it has an electric charge, which profoundly alters its properties.

II. The proportion of molecules dissociated in a given solution at a given time depends upon the nature of the solute, the dilution of the solution and the temperature.

III. All reactions between acids, bases and salts in aqueous solution are invariably reactions between their ions.

The student must not come to the conclusion that this is all of the theory, for it is not. However, it is enough for the amateur chemist if he will only perform the experiments thoughtfully. For they will involve all of the common principles of the theory.

The part of the theory most familiar to the experimenter is the section devoted to electrolysis. I think a few experiments will make the terms and principles of this portion clear.

Fill a U-tube with a solution of copper sulphate. This dissociates and is called the electrolytic (note that the ions this time are $Cu^{\bullet}$ and SO_4'). Electricity from a few dry cells is passed through the copper electrodes, the electropositive copper ions ($Cu^{\bullet}$) move to the cathode or negative electrode and the electronegative sulphate ions (SO_4') go to the anode or positive electrode. The copper ions when they reach the cathode give up their electric charges and become metallic copper. The sulphate ions (SO_4') when they reach the anode, upon giving up their charges, by uniting with water and setting oxygen free, become sulphuric acid. The oxygen comes off in small bubbles. If we examine our U-tube we see that such is the case. We see the bubbles coming off from the anode and the surrounding liquid steadily loses its color, while the cathode is covered with copper and the color deepens. This is well shown by Fig. 1.

The experiment illustrates the migration of ions and how electricity is conducted through a solution.

A question is perhaps suggested by the first part of the theory. Are there free ions in a solution of an electrolyte? Ostwald answered this question by means of a fascinating experiment. An adaptation of this classical experiment may readily be performed by the student.

Set up a U-tube as shown in Fig. 2 and fill it with dilute sulphuric acid. A rod of zinc which has been amalgamated by rubbing with mercury is lowered into the arm at A. This is the positive electrode or anode and must be connected to the zinc of the battery. A copper wire is inserted into the other arm and connected to the carbon of the battery. A current produced by three or four wet cells is then passed; there is an immediate evolution of hydrogen from the copper wire. Zinc sulphate is formed at A. This is also shown by Fig. 2.

This is very strange when we remember that if there was no current the hydrogen would be evolved at A. So if the hydrogen had to pass around the bend of the U-tube it must have done it in a very short time. However it has been proved by investigations and the calculus that it would actually have taken hours for the hydrogen to come from *A* and appear at *B*. The hydrogen however appears as soon as the circuit is closed. The natural explanation is to suppose that there are free ions already in the vicinity of *B* and that they are discharged by the current and given off from the liquid as free hydrogen.

Although at first thought this experiment does not seem so marvelous, when one considers what a great truth it teaches and its simplicity, he will very often change his mind.

We must now consider what our third division of the theory means. Ostwald has clearly pointed out four methods by which ions are formed. One of these is by the dissociation of molecules into ions in the presence of a suitable solvent. Now recalling to mind our third principle, that, all reactions are due to ions, several experiments are at once suggested. One of the best is very simple and yet convincing.

Mix in a test tube equal amounts of dry ferric ammonium sulphate and potassium ferrocyanide. There is no sign of a chemical reaction; but add a little water, a blue precipitate is

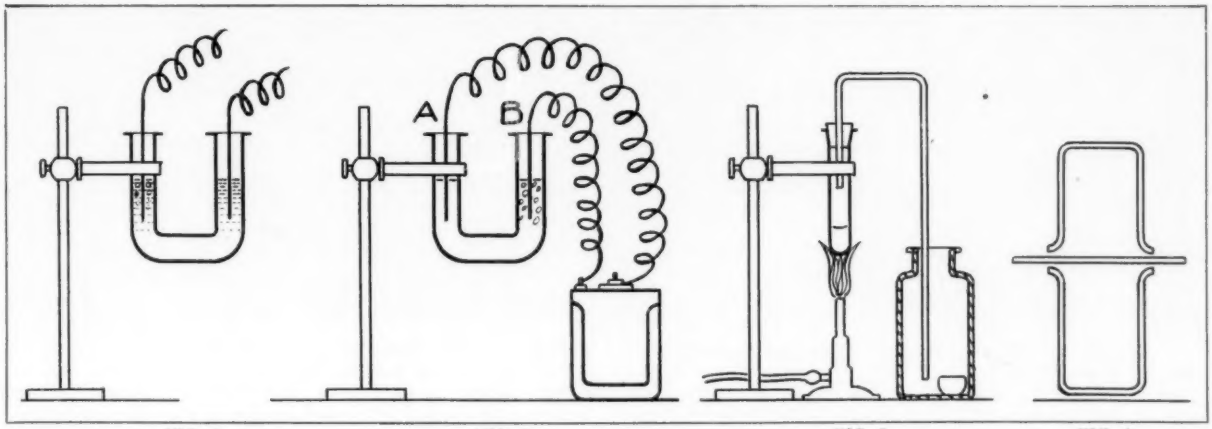


FIG. 1 FIG. 2 FIG. 3 FIG. 4

thrown down. We have ionized the two salts and then they react but not before.

Let us extend this same line of reasoning to gases. This is more perplexing for under ordinary conditions we have both molecules and ions. This is due to the slight amount of water vapor always present in the air. The obvious thing to do is to exclude the ions and have nothing but molecules present. Then there should be no chemical activity. The removal of ions thus reduces itself to the removal of water.

Ammonia gas from which all of the ions are removed ought not to turn litmus blue. Here we must bear in mind that the ions are formed by action of ammonia and water, thus $NH_2 + H_2O = NH_4' OH'$. Here we see the basic OH ion and it was formed when we added water. Now if we can remove the water from ammonia gas it ought not to exhibit a basic reaction.

All that is necessary to do this is a bottle, some extra dry quick-lime, litmus paper and ammonia. We suspend the red litmus paper in some convenient manner in the bottle, generate the ammonia gas by warming some ammonium hydroxide and conducting the ammonia gas into the bottle (see Fig. 3). Inside the bottle is a small crucible which contains the quicklime. The litmus is now blue, exhibiting the regular basic reaction showing the presence of ions and therefore water. But the thirsty quicklime is already doing its work and in two days, or three at the latest, the litmus is red. Think of it, litmus paper showing an acid reaction in the midst of one of the strongest bases—when it has all powerful water!

Again let us repeat our experiment using hydrochloric acid gas instead of ammonia and blue litmus for red. We must use phosphorous pentoxide as the drying agent. The apparatus is the same as before; but the reaction is different, *i.e.*, the litmus turns red when the acid gas is generated.

Now while we leave our gas to dry, we will try another experiment. Take two beakers of equal size and fill one with hydrochloric acid gas and the other with ammonia. Place one over the other separated by a piece of glass (see Fig. 4). They are both clear. Remove the glass and allow the two to mingle. There is a white cloud formed which if permitted floats lazily about in the air.

You will note that we took no care to dry the gases and that there was a very vigorous reaction, indicated by the white clouds.

Let us return to our hydrochloric acid gas: if it is highly dried, the litmus turns blue just as it turned red in ammonia, *i.e.*, in opposite directions to what is expected. If both gases are highly dried we may mix them; however, if we have taken care not to expose the open bottles to the water of the atmosphere, we will only have a slight cloudiness at most.

Like the proverbial lamb and the lion, these two gases, ammonia and hydrochloric acid having such a great affinity for each other remain side by side inactive. It is truly wonderful! To further confirm our theory allow access to the air; the dry gases begin to fume because of contact with the water vapor of the air.

Some other experiments of a similar nature at which the youthful scientist may tax his skill and find himself well repaid if he succeeds are:

Dry chlorine does not act on fused metallic sodium.

Dry sulphur, boron and phosphorus do not burn in dry oxygen.

Dry hydrochloric acid does not attack carbonates.

One of the most conclusive experiments of all was performed before the Chemical Society of London. A wire serving as a handle was wrapped around a piece of dry metallic sodium, which was then plunged into pure, dry sulphuric acid. At first there was a flash of light caused by the few ions formed on the surface of the metal as it moved through the air to the acids. After that the sodium remained suspended in the sulphuric acid as if it were so much kerosene. A hint of what would happen if ordinary chemicals were used is given by that first flash of light. I am afraid that it would wreck some real estate.

The above experiments and many others which I might mention show conclusively that molecules have little or no chemical activity, and that ions are the chief agents causing chemical actions. We can now see why inorganic reactions proceed rapidly to the limit, while organic reactions take place more slowly. The inorganic compounds contain the strong bases, acids and salts which are strongly dissociated compounds. Thus there is an abundance of ions and that means lively reactions. Whereas the organic compounds are weakly dissociated and the reactions proceed slowly because of the few ions present.

CARBON-DIOXIDE AS A FERTILIZER

Some very remarkable experiments have recently been made in Germany, with a view to ascertaining plant growth, by furnishing plants with artificial supplies of carbon-dioxide or "carbonic acid gas" in addition to what they ordinarily obtain from the atmosphere. The idea is to irrigate fields with carbon-dioxide obtained from the exhaust gases of motors and furnaces. An account of the process employed is given by a German scientist named Riedel, in the German engineering journal, *Stahl und Eisen*. The first tests were made in a hot-house, the gases being diluted until they contained one half of one per cent of carbon-dioxide. This additional carbon in the atmosphere produced unexpected results, the yield of cucumbers being twice as great as in the control plants and that of tomatoes nearly three times as great. Equally good results were obtained in the case of plants grown outside. The carbon-dioxide was furnished here by means of perforated pipes, which traversed the field. Mr. Riedel estimates that an industrial furnice furnishing 1,000 tons of iron per day, yields a sufficient amount of exhaust gases to fertilize 4,000 tons of potatoes.

Severing Metals by Oxidation

Some Problems of Flame Cutting in Which Authorities Disagree

By Pierre E. Haynes

THE art of severing metal by oxidation is not yet twenty years old and it has been averred that our knowledge of the subject is quite complete and comprehensible. Its companion, the art of welding, is several thousand years old and its first practice has marked the birth of every civiliation on the face of this planet. Who will venture that with all this ancient development and modern research, the world's knowledge of welding is complete and comprehensible not to say simple!

The art of severing metal by oxidation is in its infancy. We know we can cut some metals because it is being done but the exact mechanism of cutting is not yet well understood.

Only a year ago the published word of erstwhile authorities contained statements that cast iron could not be severed by the oxidation process. Three and one-half per cent of carbon, the self-same material that furnishes the artificial heat of the world prevented oxidation of iron. Why couldn't iron be oxidized in the presence of carbon when carbon is more easily combustible than the iron itself? It seemed so simple that a simple answer was required. Cast iron, they said, melted below its temperature of ignition and freezing slag prevented the raising of the iron above its melting point. This explanation was so generally accepted that with a few exceptions no attempts were made to develop the art of cast iron cutting.

Witness today the effective cutting of cast iron with standard equipment. Popular authorities are falling over themselves to whisper the reason in the ear of the public. As a matter of fact, men who are devoting their lives to the study of flame-cutting are not yet sure of the complete explanation. They cut and know they cut because they cut. If they loved anything better than the truth, theories far more rational than many popularly promulgated might be presented.

Because it constitutes one of the major elements of the cost of steel cutting and because it is one of the materials not prepared by the consumer himself, commercial cutters are prone to assign all variations in cutting cost or quality of the oxygen and in support of this contention present cost determination and other data which indicate the undesirability of nitrogen as an impurity. A recent writer points dramatically to the overwhelming cataclysm which would result if nitrogen were combustible. "A lightning stroke," says he, "would explode the beneficent atmosphere surrounding the earth." While not recommending nitrogen as a commercial fuel, one must remark that every lightning stroke does form nitric acid; and deposits or nitrates, at favored spots on the earth's surface, indicate that in the aggregate large amounts of nitrogen are being burned. Not to be outdone by Nature our Norwegian friends drew lightning strokes from waterfalls for the purpose of burning nitrogen to form the world's most valuable acid.

With respect to burning or combustibility, nitrogen differs from iron in measure only, and as a matter of fact, the difference is the same for practically all substances. Some substances burst into flame immediately upon exposure to air or oxygen while others like wood, usually require a flame for kindling. Iron kindles in oxygen at red heat, while a mixture of acetylene and oxygen may be ignited by allowing it to impinge on iron below its temperature of incandescence. The kindling temperature of nitrogen is high, but what careful observer has failed to detect the odor of nitric acid where steel cutting is being performed?

Oxygen is not satisfied with its ability to attack successfully its plebeian neighbors and form new substances. This aristocratic gas combines with itself and forms ozone, king of oxidizers. That it combines with itself is proven by the fact that three volumes of oxygen form only two volumes of ozone. The unmistakable odor is usually present wherever oxyacetylene cutting is being performed. Whether it enters into the actual process of cutting has never been determined. The fact remains that oxygen combines with itself with a negative heat of combustion.

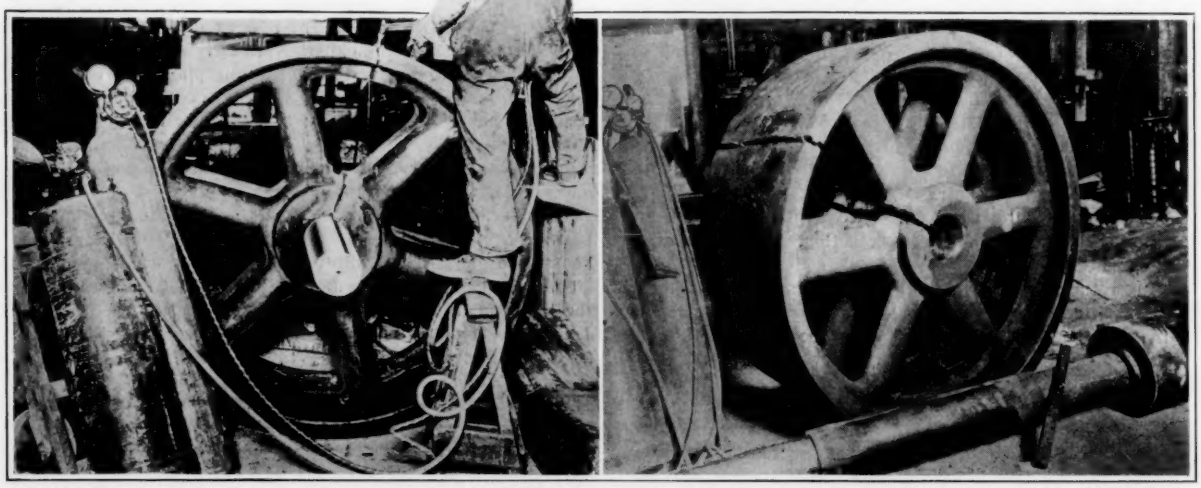
Stripped to known facts, the process of flame cutting of steel consists of the elevation of some spot to the kindling temperature, the application of oxygen and the progressive direction of the oxidizing jet along the desired path. The requirements are:

1. A preheating flame hot enough to bring the iron to its ignition point without delay.

2. The intelligent adjustment and direction of the cutting appliances to maintain highest efficiency and results of desirable quality.

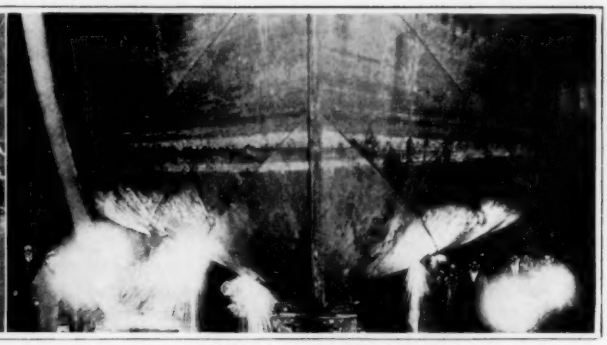
3. Oxygen of suitable quality and at the correct pressure and jet velocity.

A wide range of fuels may be found to meet the first re-



EXAMPLES OF CAST IRON CUTTING—THOUGHT IMPOSSIBLE A YEAR AGO BECAUSE OF SUPPOSED CHEMICAL OBSTACLES

CUTTING OUT RIVETS TO REMOVE SHELL PLATES FROM HULL OF VESSEL



CUTTERS AT WORK ON LOWER SHELL PLATES OF A STEEL SHIP

quirement although the use of poorer fuels usually results in a greater expense for oxygen and labor.

The personal element is by far the most important in the determination of the cost of cutting. A 12 per cent variation in cutting cost, with all other conditions constant, would be considered excellent from the standpoint of reproducibility, and a 20 per cent variation is not at all uncommon for workers under ordinary observation.

The pressure and jet velocity of the oxygen are important because they determine the amount of iron oxidized and the cleanliness and dispatch with which the molten oxides are removed. They are matters of torch design and adjustment. Authorities seem to agree fairly well regarding these points but disagree with regard to the effect of the various impurities found in the commercial oxygen. Proponents of the use of electrolytic oxygen insist that regardless of the nature of the impurities the small differences in the quality of commercial oxygen is an effective element in the cost of cutting steel and that at even purity, electrolytic oxygen is superior to "liquid air" oxygen because of the combustibility of hydrogen and certain alleged villainous qualities of nitrogen. We have certain specific allegations made in a recently published article, the accuracy of which it would be distinctly improper to question without having observed the test. It is correct however to question the assumption that the variation in results is due to the quality of the oxygen if the method of test is incapable of detecting this fact.

It is stated that tests were made "with each oxygen adjusted at its own best pressure and working conditions." Long and bitter experience has taught that comparable results are never possible unless all conditions of cutting are reproduced with the exception of time for each individual determination. While it is reasonably safe to assume that each operator will adjust his appliance to the best possible conditions as they appear to him, there is no assurance that any of the operators are competent to judge this condition absolutely with the crude means at their disposal and any variation in results may as well be assigned to the difference in adjustment as to variation in oxygen purity. Scientific practice demands that all variations except the one to be measured be eliminated or considered in judging the final result. Results such as these recently published cannot be considered more than qualitative.

It has been stated that the impurities in "liquid air" oxygen suffer a much greater quantitative variation than those in electrolytic gas. While not able to speak for the whole oxygen industry I believe that I am safe in saying that there is nothing inherent in any of the so-called liquefaction processes that would prevent the limit of variations to much smaller values than those referred to. It is quite possible that the author of the recent paper is referring to commercial oxygen of several years ago. The purity of all commercial oxygen has been improved greatly in the last few years. Electrolytic oxygen manufacturers being forced to increase their purity because of the inherent risk in the compression of oxygen containing hydrogen. This risk is still present and, although in much lesser degree, is always a potential one until machines and men are rendered perfect. The cost of producing a reliably safe product is reflected in the greater cost of production of electrolytic oxygen to which attention has been frequently called.

In one of the recent articles considerable stress is laid on the advantage of electrolytic oxygen over "liquid air" oxygen because of the absence of nitrogen. The total absence of any impurity other than hydrogen is accounted for by the fact that electrolytic oxygen is made from distilled water. It would be impossible to state the total amount of electrolytic oxygen made by the use of distilled water but in as much as good filtered water has been found satisfactory it is doubtful if the use of distilled water is general. The statement that electrolytic oxygen is made from distilled water is, however, in error since it is necessary to add some substance to make the water conduct the electric current. Commercial caustic soda is usually used for this purpose and unless the soda is fairly pure there is some danger of pollution of the products. Impurities originating from the water or electrolyte are of relatively no importance, however, except for gases dissolved in the water which are sure to appear in the oxygen.

Careful analyses of electrolytic oxygen always disclose from 0.1 per cent to 0.3 per cent of nitrogen which may come from the gases dissolved in the electrolyte or may diffuse into the cylinder which stands empty with the valve open. Regardless of the source this small amount of nitrogen seems always to be present. On the other hand the impurity of oxygen obtained by means of the liquid air process, consists of nitrogen and argon—not of nitrogen alone.

CUTTING PLATES TO PATTERN IN THE SHIPYARD

If oxygen impurities are to be considered in the light of cooling agents we must consider them from the standpoint of their percentage by weight and not volume. On this basis nitrogen is approximately 50 per cent by weight of the impurity of electrolytic oxygen and 60 per cent by weight of the impurity of "liquid air" oxygen. Argon, because of its low specific heat, is much more desirable than either hydrogen or nitrogen. As a cooling agent hydrogen stands out as a notorious offender, its specific capacity for the conduction of heat being approximately six times that of any other gases in the flame.

As proof of these statements, theoretical calculations of the temperatures of the inner cones of oxyacetylene flames have been made using electrolytic and "liquid air" oxygen at various concentrations.

FLAME TEMPERATURE—DEGREES CENTIGRADE ABSOLUTE

	98%	99%	99.5%
Liquid air oxygen	5040	5050	5060
Electrolytic oxygen	5035	5048	5060

In the calculation of the above the nitrogen impurity of electrolytic oxygen was maintained constant at 0.2% (an average experimental value) in order to indicate that as hydrogen was eliminated the flame temperature of "liquid air" oxygen was approached. The percentages of the argon and nitrogen in "liquid air" oxygen were the amounts found in actual practice. The above values do not include the effect of the higher heat conductivity of hydrogen.

In practice, the above differences in flame temperatures would never be detected. They are given for the purpose of showing that small as the effect may be they are unfavorable to the electrolytic oxygen.

If we argue that the heat yielded by the combustion of hydrogen is of value we again find ourselves up against a similar condition. If we try to find the effect in the preheating flame, we learn that acetylene has at least four times the net or low heating value of an equal volume of hydrogen so that the heat added to the flame by 1% of hydrogen impurity is:

$$.01 \times .25 = .0025 = \tfrac{1}{4} \text{ of } 1\%$$

In addition to this it has been determined that the preheating flame supplies less than 30% of the total heat available in cutting, the balance coming from the combustion of the iron. The effect of the hydrogen impurity is therefore further reduced to at least

$$.30 \times .0025 = .00075 \text{ or } 75/1000 \text{ of } 1\%$$

What reputable engineer will risk his good name by assigning commercial advantage in a technical process to the addition of less than 1/10 of 1% of the available heat?

Let us then turn to the contention that the nitrogen expands and dilutes the oxygen. In the first place all gases have the same coefficient of expansion with heat and it is absolutely impossible to change the oxygen percentage in a mixture by heating it. The oxygen expands at the same rate as the impurities and no change in the constituency is possible. On the other hand, expansion (or dilution) of the oxygen would take place if the gas were perfectly pure because any gas expands to larger volume when heated at constant pressure.

And what, pray tell, becomes of the much-to-be-desired hydrogen impurity as it passes through the flame and kerf to be burned in the outer envelope? Has it not also expanded with heat; does it not also occupy space; has it not absorbed heat? In fact is there any undesirable attribute that nitrogen has which is not also possessed by hydrogen in the same or greater degree. Only one real advantage is claimed and that is the fuel value of the hydrogen, but this quantity is ridiculously small and negligible for all purposes.

Certain peculiar properties claimed for nitrogen by a recent writer include that of being expanded by heat in such a way that cooling of the nitrogen results. A student observing experiments with liquid air for the first time and being much impressed by the evolution of vapor at such low temperatures, exclaimed, "It's so hot it's cold"! So with our friend's nitrogen impurity—it is hot because it is cold and vice versa.

It seems almost impossible that claim for surface hardening on account of a nitrogen impurity in the oxygen will be accepted generally. In the first place the hardening of steel is controlled almost entirely by its carbon content and rate of cooling. If, as is claimed, nitrogen containing oxygen cuts slower than that containing hydrogen, it appears reasonable to expect that the slower operation will give the slower cooling and result in softer surfaces. In addition we must not forget that the oxygen jet aspirates large amounts of air into the kerf and that the hot surface of the metal almost invariably cools in a bath of air so that the nitrogen in the flame from the "liquid air" oxygen is a small per cent of the total nitrogen. This same set of conditions will also be found with the use of electrolytic oxygen. The preponderance of atmospheric nitrogen renders the fractional effect of the oxygen impurity negligible.

CUTTING A 44-INCH STEEL RISER

Owing to upright position of riser and consequent horizontal cut, the corners were first cut so as to reduce to smaller square cross section, the process being repeated on the reduced squares until the jet easily penetrated the remaining stem.

The question of surface hardness has not been raised previously except in connection with the use of hydrogen as a fuel instead of a hydrocarbon gas. It was claimed that hydrogen used as fuel produced a steel surface free from carbonization. At first glance the statement appeared logical but a casual analysis showed that the steel burned in the process of separation yielded sufficient carbon to account for the maximum carbonization found. A microscopic examination of surfaces cut with acetylene and hydrogen used separately as fuels failed to discover any appreciable difference in the amount of carbonization.

The carbon contents of the samples before cutting were less than 0.2 per cent and after cutting it was found that a thin layer of metal on the cut surfaces had had its carbon content increased to 0.9 per cent or greater. Carbon had been added in the case of the oxyhydrogen cut as well as that of oxyacetylene. In the case of the oxyhydrogen cut, the only

source of carbon was the steel and the amount of carbon added was fully as great as in the case of the oxyacetylene cut. It would be grossly unfair to insist that acetylene is a source of carbonization when the use of a "no-carbon" fuel results in carbonization. The carbonization was a result of the avidity of molten steel for the carbon in adjacent burning steel—the origin was the same in both cases.

The cutting of steel is approximately 70 per cent efficient or in other words the oxygen required to burn all the iron removed to oxide is about 70 per cent of that usually used. It is physically impossible to obtain complete mixing of iron and oxygen in the small time allowed in the kerf so that there will always be some oxygen and some iron uncombined. It is quite improbable that the conditions of theoretically perfect cutting will be approached closely and the possible increase in cutting efficiency is less than the advantages extravagantly claimed for some apparatus and materials. As competition grows keener and materials and apparatus approach perfection, differences will be smaller and more difficult to detect. The inability to disprove extravagant claims must not be confused with absolute proof that they are *bona fide*. Not only must experimental data be carefully studied but they must be considered in a rational, reasonable manner, free from bias and devoid of that amateurish enthusiasm which is generally present where new and interesting lines of investigation are being opened up. One can always find technical differences because they are always present and we should always question ourselves as to their relevance and measurable effect.

Upon the shoulders of the engineering profession is a great responsibility. The great complication of our industrial life demands interpreters who not only comprehend the facts but sense the value of a true and accurate translation of them into terms generally understood. This is one of the functions of the engineer—the rational interpretation of technical information in the light of fundamental scientific principles.

Metal Substitutes—II*

Use of Various Metals and Alloys in Germany to Replace Those Made Scarce by the War

By General Director Albert Wuerth

With Annotations by C. Powell Karr, Ph.B.

(CONCLUDED FROM OUR ISSUE OF JANUARY, 1921, PAGES 54-58)

UP to the introduction of a zinc alloy for which already a continuous investigation had been arranged, brass was specified. This reversion resulted in slowing up the output from the foundries and workshops. The tensile properties were always good, but were kept just within the limits demanded by the analyses. Simultaneously there was an investigation in process to make a cast-iron serviceable for fuses which will be reported later.

After the first failure with zinc fuses there came into consideration chiefly copper and aluminum as ennobling additions to the zinc alloys. They were regarded as inferior in tensile strength by Engineer Schulz (see Schulz's experiments concerning a method for the improvement of zinc—*Metall und Erz*, 1916, p. 279) which will be referred to later. The known binary alloys in the first place may be distinctly recognized by the reaction of a single metal such as aluminum or copper upon zinc.

An addition of 3 per cent aluminum gave a rupture charge of 5 to 6 kilograms per square millimeter, or (7,112 to 8,534 lbs. per square inch), 4 per cent a rupture charge of 9 to 12 kilograms per square millimeter, or (12,801 to 17,068 lbs. per square inch)

Six per cent gave a rupture charge of about 16 kilograms per square millimeter or (22,757 lbs. per square inch) with a corresponding increase of hardness.

The ternary alloys of zinc, copper and aluminum with an addition of 0.5% Cu. plus 1% Al. gave a rupture charge of 5 kg. per sq. mm.

2.0% Cu. plus 3% Al. gave a rupture charge of 10 kg. per sq. mm. or (14,223 lbs. per sq. inch)

3.0% Cu. plus 6% Al. gave a rupture charge of 15 kg. per sq. mm. or (21,335 lbs. per sq. inch)

4% Cu. plus 9% Al. gave a rupture charge of 20 kg. per sq. mm. or (28,446 lbs. per sq. inch)

6% Cu. plus 10% Al. gave a rupture charge of 25 kg. per sq. mm. or (35,560 lbs. per sq. inch).

After the reversion to brass, several alloys were very soon recommended, which after making a selection were immediately introduced.

The structure of No. 1 alloy (see Table on page 147) revealed stem-like branches at the margins or edge. The cohesion of the individual crystals failed partially. In consequence of the coarse crystallization of the structure the foam cells were strongly developed. The tenacity was low. Within and at the boundaries of the crystal aggregates fractures appeared. The structural aspect of Alloy No. 2 is like that of the aluminum-copper alloys. The structure consists of small crystals upon the cast surface that are distinctly visible. Here also appeared skeletons of solid solutions.

In the No. 5 alloy (see Table) the structure allows the same remark to be applied to it, yet here the composition is only a little above the eutectic (5%). Indications of segregation, in addition, were perceptible, although in small quantity.

From the exhibition of the chilled structure of the aluminum-zinc alloys it is to be gathered that an aluminum content of 5 per cent lies along the eutectic line, which, at 380° C. consists of a solid alpha solution with less than 1 per cent aluminum plus a solid beta solution of the combination Al_2Zn. At a lower temperature, 256° C., the beta solid solution breaks up into alpha and gamma crystals; the latter containing a greater amount of aluminum than the solid beta solution. An alloy with 8 per cent aluminum has, accordingly, at the ordinary temperature, a structure consisting of alpha and beta solid solutions close to their eutectic.

Remarkable is the segregation of the No. 7 alloy (see Table for its composition) which in the various specific weights are confirmed by the solid solutions alpha and gamma.

In addition to the above named alloys: zinc (99 per cent) was drawn into bars for the purpose of conversion into fuses. These were cut into pieces and at 100° to 130° C. were compressed into zinc fuses. The No. 1 alloy (see Table for its composition) should be the lowest in tin and copper; no antimony and the least amount of aluminum or none at all. They were merely an overload and the composition recommended at that time must be regarded merely as such. From a metallurgical standpoint the introduction of No. 3 alloy (see Table for its composition) was considered inadmissible. The ordinary commercial refined zinc, on an average, contains almost 1.3 per cent Pb. In addition to 1 per cent Pb. this would yield 2.3 per cent Pb. Since however the solution capacity of zinc for lead at the utmost amounts to 2.5 per cent and at the pouring temperature of the fuses—the content of tin of 2 per cent has no effect—the solubility at the maximum is put up to 1.5 per cent Pb., it must without further discussion form segregations at the cooling point of the fuses. This conclusion is also confirmed by the solubility curve of lead and zinc by Spring and Romanoff (P. Goerens. Introduction to Metallographie, p. 21). According to that data the lead-zinc alloys offer a notable example of metal solutions whose

*Translated from *Stahl und Eisen*, April 1 and 29, 1920.

solubility in the molten state is very fluctuating. While at 920° C. the miscibility of both metals is unlimited, but its capability of mixing declines with the lowering of the temperature. In the still homogeneous fluid mass there are formed, then, two layers: one rich in lead and one poor in lead. In freezing a further separation takes place.

The alloy No. 6, with zinc 98 per cent and iron 2 per cent, metallurgically has also been found not unobjectionable. If the iron is combined with the zinc up to about 5 per cent, then, even at 2 per cent, the zinc-iron alloy is extremely brittle and hard, even to the naked eye. With a somewhat higher percentage of iron, the fracture is conchoidal; furthermore such an alloy is but slightly stable. As a consequence these alloys could not be considered available for fuse castings. The alloys Nos. 4 and 5 (see Table for their composition) with 4 to 5 per cent aluminum have a decidedly coarse crystalline structure and for that reason are also objectionable. What appeared to be most conformable to the experience at that time is the one with a composition of 95 per cent Zn, 1 per cent Sn., and 4 per cent Al.

Justification for the use of this alloy is based chiefly on the large percentage of zinc with little or no tin or copper and as an additional recommendation a superior machining quality and hydraulic impermeability. Concerning tensile strength, analyses, etc., no specifications would be published apart from the hint that the fuses must not be brittle. (This is one of the German secret alloys whose solution capacity and metallographic characteristics they refused to reveal, because, no doubt they were utterly satisfactory and of a high order.) Since it was conjectured that the specified fuse alloys did not meet the highest claims to tensile strength, a suitable pressure investigation of the fuses of these alloys was undertaken, which called for a very special remodeling of the materials.

The fuses were preheated at various temperatures, and by this treatment, the former fine-grained mass was transformed into a radiated fibrous structure. In the bursting charge and cleavage test the fuses were extremely tough; nevertheless the alloy had the disadvantage that the material, particularly in the fuses, was transformed into layers or striae and separated into zones distinctly outlined from one another. This special phenomenon arises from the fact that the stamping or punching pressure itself is rectilinear until it is transmitted to the lower, small pivot. Since the stamping of the upper finished profile of the fuse possesses but little capacity for machining, the action gave to the form of the fuse an inner neutralized and sharply circumscribed cone, with a fine-grained structure so that the additional roll-shaped material piled up, as may be distinctly seen in the original test sample itself. Upon the basis of these results, the further proposed experiments were cut short, since a completely unobjectionable cast fuse by reason of its homogeneous composition and texture appeared to be better than a stamped or pressed fuse from the same alloy.

It was shown however that the requirements for the strength of the fuses with the various alloys which had been tried out, had not been reached. On this account, the production of the zinc fuses from the alloys mentioned along the whole line had to be interrupted and aluminum or brass fuses had to be resorted to in their stead according to the relative production in reserve of those metals. This reversion, in return, led to trouble in the foundries as also in the operations in the machine shops. Only stamped or pressed zinc fuses were permitted to be made from pressed zinc bars.

In the meantime further research work with zinc alloys had not remained idle. For this series of investigations there was chosen a zinc alloy that had been introduced into Austria long ago. Its composition was from 4 to 6 per cent Cu., 2 to 3.5 per cent Al., balance zinc. Of additional constituents the maximum permissible was 2 per cent. Therefore the lead could not be over 1.3 per cent, tin not over 0.5 per cent and iron not over 0.4 per cent. To this as a rule copper and aluminum were not to be below 7 per cent, nor more than 9 per cent. As a rule the alloy was worked with 5 per cent Cu. and 3 per cent Al., with the endeavor to hold the rest of the admixture as low as possible.

The structural formation exhibited numerous crystallites of the solid solution of copper. On the cast surface the crystal structure is distinctly visible. Generally the grain size increased as the copper diminished, which, by comparison with the alloys 33 and 37 (see Table for their composition) is recognized. The structural formation discloses bright crystal aggregates embedded in a dark matrix. Skeleton crystals of a solution poor in copper were visible as they were in alloy No. 31.

The behavior while in a molten state indicated the correct treatment for all of the above established points for castings completely free from all objections. The rupture charge, impact, bursting, cleavage tests, machining properties and impermeability were good.

One after another, now, the various changes in the zinc alloys were to be carried out. If also, by this means, the transient succession of the finished fuses was interrupted, then the interruption with a better prospect of success on account of the construction might still be put into operation. With a correct check on the transient succession the treatment of the alloy, here and there, must be interrupted by the interpolation of alterations of the aluminum alloys because the latter for the kinds of fuses previously decided upon must still be retained. The aluminum alloys are to be referred to later.

On account of the great scarcity of copper it was necessary to change the unobjectionable zinc alloy No. 31 (see Table for its composition). The first change made related to the lessening of the copper as well as the aluminum respectively. The alloy contained 3 per cent to 4 per cent Cu. and 0.5 per cent to 1.5 per cent Al. The structure of No. 35 alloy is very crystalline and dense. The light crystal aggregates appear to be few in number.

Besides, on account of the varied amounts of copper and aluminum the remaining determinations should hold good. Nevertheless it was immediately shown that this alloy was not so unobjectionable as the preceding one. The tenacity fell, although it always remained above the lowest specified limit. The correct check on the required pouring and chilling temperatures was of much greater importance than in that of the first alloy. Here, therefore, is a case, which by slight changes in the material of the alloy was at first perceptible in the velocity of the cooling. The size of the crystals and the structure and with them the hardness and tenacity depend upon slight temperature differences. (E. Preuss, Berlin, 1913—The Practical Application of the Testing of Iron by Etching Methods.) The alloy had to be abandoned. By increasing the copper and especially the aluminum an alloy of 4 per cent plus 0.5 per cent Cu. and 3 per cent plus 0.5 percent Al. was introduced. On account of the increase of the copper, and because of the doubling of the aluminum it showed a greater toughness, at the same time the permissible shrinkage was adjusted upward. The great lack of copper was forced afresh for consideration, in spite of the unfortunate experience which came to pass from a former effort to economize in copper. As a compensation for the reduction of copper a slight increase of aluminum was provided for.

An alloy, therefore, was obtained with 1.25 per cent Cu. and 3.75 per cent Al. With this alloy the tensile strength fell decidedly. The structure was coarsely crystalline and put forth phenomena that should be more closely examined. The structural formation of No. 37 (see Table for its composition) is similar to that of Nos. 35 and 39. Also here the structure is clearly visible on the surface of the casting. Shortly after the casting was poured the rupture charge gave a tenacity that was directly above the specified minimum limit. About three months later, in a remarkable manner, fractured fuses of the same alloy and from the same place gave an abnormally

Alloy No.	Zn. %	Sn. %	Al. %	Cu. %	Pb. %	Fe. %	Si. %	Mg. %	Pouring Temperature °C.	Chilling Temperature °C.	Tensile Strength Kg. per Sq. mm.	Tensile Strength lbs. per sq. in.	Remarks
1	95	1	4	....	....	....	....	....	510–530	210–230	8.3– 8.1	11805–11531	.....
2	92	6	....	2	....	....	....	....	500–530	200–220	7.3– 7.6	10383–10810	.....
3	97	2	....	....	1	....	....	....	.....	.....	.....	.....	.....
4	96	....	4	....	....	....	....	....	.....	.....	.....	.....	.....
5	95	....	5	....	....	....	....	....	500–530	200–225	10.7– 9.8	15219–13939	.....
6	98	....	....	....	....	2	....	....	.....	.....	.....	.....	.....
7	92	....	8	....	....	....	....	....	500–530	200–225	.....	.....	.....
15–16	....	5.88	91.3	2.21	0.11	0.5	....	....	720–730	290–310	8.7– 9.8	12374–13939	.....
17–18	28.66	....	70.11	trace	0.3	0.48	0.45	....	650–670	250–270	14.2–12.7	20197–18064	.....
19–20	13.66	5.07	79.56	0.89	0.26	0.56	....	....	710–720	280–350	20 –18.1	28447–25744	.....
21–22	93.7	1.21	3.87	0.33	0.89	trace	....	....	510–530	210–230	8.3– 8.1	11805–11531	Dull sound
23–24	91.74	5.35	....	2.02	0.65	0.24	....	....	500–530	200–220	7.3– 7.6	10383–10810	Dull sound
25–26	93.02	0.43	5.52	0.05	0.80	trace	....	....	500–530	200–225	10.7– 9.8	15219–13939	.....
27	90.55	0.33	8.05	0.18	0.89	trace	....	....	500–530	200–225	.....	.....	.....
31–32	90.90	0.13	3.15	5.25	0.57	trace	....	....	525–545	230–250	15.4–14.2	21904–20197	Clear ring
33–34	93.10	0.39	2.75	3.10	0.66	trace	....	....	510–530	220–240	11.6–12.9	16498–18348	Dull ring
35–36	94.24	0.12	0.88	3.67	1.09	trace	....	....	490–510	190–210	10.9–11.1	15504–15788	Dull ring
37–38	93.99	trace	3.83	1.32	0.86	trace	....	....	510–530	215–240	9.2–10.0	13086–14223	Dull ring
.....	.....	....	.....	....	....	.....	....	....	.....	.....	10.9– 8.2	15504–11633	Clear-Dull ring
39–40	93.75	0.12	3.25	1.89	0.99	trace	....	....	520–540	220–240	11.0–11.1	15646–15788	Dull ring
.....	.....	....	.....	....	....	.....	....	....	.....	.....	10.7–10.8	15219–15361	.....
42–43	7.04	....	90.12	....	....	2.07	....	0.77	730–750	280–300	12.9–15.0	18348–21335	Thread sheared
44–45	12.50	....	84.78	....	....	1.68	....	1.04	720–740	270–290	16.7–15.7	24153–22330	.....

TABLE OF THE COMPOSITION OF ALLOYS

low tenacity, one that fell far below the specified limit. To be sure the cleavage and bursting tests exhibited a satisfactory toughness, nevertheless, along with the separate bursting in the fuse bodies there appeared concentric fractures, which, without further discussion of them led to the conclusion that in the internal formation of the structure at the point of fracture there was recognized an additional fine-grained (almost amorphous) structure. Up to the central portion, forward, it almost immediately passed into a coarse crystalline core. Segregation phenomena were not chemically established, since accurate analyses of the marginal and middle zone yeiled no essential variations. The slight difference was wholly accounted for by the amount of copper present. Also with the rupture charge there appeared both a coarse and a fine formation distinctly observable. The raising of the pouring and chilling temperature limit, at least within the allowable experimental error, resulted in no considerable effect upon the tenacity. Merely an investigation, which however for practice in quantity manufacture did not come into question, in which the drop of the temperature between the chilled and the cast alloy was extraordinarily high (which was therefore the case with a very cold chill) yielded, in consequence of the rapid solidification, a higher resistance to rupture, but at the cost of the ductility; the bodies were brittle. Besides, with a greater rapidity of cooling the piping extended (as previously indicated) so deep into the piece that it was apt to become unusable.

On the whole it must be stated that the fuses from the new alloys do not meet the required demands as to machining capacity and tenacity or at any rate that they come too near to being practically unusable. The homogeneity and density of the metal left nothing to be desired. This phase it showed quite clearly, when the permissible shrinkage for the amount of copper specified was found to be lower than claimed. Thus the copper fell below 1.25 per cent. The tenacity value then fell significantly below the specified minimum.

In machining the fuses the new alloy immediately exhibited faults that earlier were unknown. In the sheathing of certain joints or in the countersinking operations of certain drill-holes, fractures originated or metal parts became detached by bursting. This brittleness of the metal was traced back to the formation of coarse crystal surfaces that have no connection with one another. (Irregular crystallization is always an indication of inhomogeneity and probable weakness.)

Since the results of the investigation were obtained as described, two new alloys were immediately specified with an increase of the copper and a decrease of the aluminum to 2.5 per cent Cu. and 3 per cent Al. or 2 per cent Cu. and 3 per cent Al.

The structure of No. 39 alloy (see Table for its composition) is coarsely crystallized corresponding to the reduced amount of copper. The margin displayed stem-like fractures that in the cleavage tests were distinctly visible. Also there appeared ruptures paralleling the edges of the fuses on account of the slight cohesion of the separate crystals of the marginal zone with those of the central cores. The structural formation displayed light and dark crystals that were partly aluminum-rich and partly copper-rich.

Furthermore, these alloys did not turn out especially well, because of the so-called "Aging of Metals" arising after monthly changes in the structure of the fuses. In the metallographic investigations (undertaken at the fire works laboratory at Spandau) it was found that in the separate crystals of the alloy, in the course of time, parallel rents or fissures appeared.

By this means the tenacity of the fuses was lowered considerably. This is an interesting evidence of the so-called life phenomena or internal growth or change of inorganic materials. (A great deal of information exists in the literature, but is not brought together in a tangible shape for reference, concerning the effect of aging upon many zinc-aluminum alloys. It is not to be wondered at that the general director, Albert Wuerth, should designate such changes or growth as a remarkable phenomenon, because at the time it was a new development and but little known. The writer calls to mind an instance of the same character, and occurring during the recent war, in which a small propeller-shaped wheel, with four blades, used for stirring purposes in the chemical laboratory, supposed to be immune to organic acids, or sulphuric acid, appeared to be sound and homogeneous at the time of casting, but three months later, disintegration had set in, marked by crumbling at the edges, and fissures like season cracks made their appearance at the junctions of the blades with the central stem. The changes occurred so rapidly after having started that the use of that zinc-aluminum alloy had to be abandoned for that purpose. It had a composition of about 15 per cent zinc and 85 per cent of aluminum.)

In this case, as Czochralski says, in consequence of the internal condition of the alloy, there occur transformations of the structural constituents within the body without an external irregular treatment of the castings, whether this be

through the addition of heat or other factors, such as pressure, concussion, etc. With this internal variation of enclosing formations that occur, a force must be exerted that is very great, as in that one case immediate crystals were broken. In the metallographic laboratories of the Brothers Körting A. G. in Körtingsdorf in Hannover-Linden, it has been the intention to investigate bodies of that kind later, at repeated intervals of three months, in order to note whether there is any evidence of a further life or continuing growth in metal bodies that would lead to a continuous development or even to the ultimate destruction of the bodies.

That some days after the casting complete changes occur in the interior structure is known. On this account the castings must not be disturbed until the greatest of changes (self-hardening) has taken place.

Official attention was paid, quite particularly, to the tin-free aluminum alloys to be mentioned later, with additions of magnesium. (J. Czochralski—The life duration of *Metals-Giesserei-Zeitung* [Berlin], Jan. 1, 1915, p. 1)

It is still cited that at times many separate zinc fuses were replaced by iron fuses that were struck up in a die or made of cast-iron. Such fuses, or the greater part of them that were easy to finish, were made of cast-iron, and for parts unsuitable to be made of cast-iron, cylindrical pieces of zinc were stamped or pressed in such a way that they became an integral part of the fuse.

For the aluminum fuses the following alloy was specified: Cu. 1.5 to 3 per cent; Sn. maximum, 3 to 6 per cent; Fe. maximum, 1 per cent; Sn. maximum, 2.5 per cent; not less than 90 per cent. Another alloy consisted of 95 per cent Al., 3 per cent Sn. and 2 per cent Cu. The question of the scarcity of tin was always pressing. On this account the experiments with 10,000 fuses of various alloys were suggested:

1. 4.5 per cent Cu.; 0.5 to 0.75 per cent Pb., remainder aluminum.

2. 8 to 10 per cent zinc, remainder aluminum.

In workable properties both alloys were unserviceable, because all the shops were rapidly exhausted by the hardness of the combinations and the ensuing dullness of their cutting tools. On this account an alloy containing but little tin was specified:

Cu. 2 to 3 per cent; Sn. 2.5 to 3.5 per cent; Zn. maximum, 2.5 per cent; Fe. maximum, 1.5 per cent; Si. 1.0 per cent.

In the meantime the investigations were continued, in order to obtain an alloy free from tin.

Among the light metals was found magnesium, a metal that added to other metals, to some degree, unhesitatingly gave a possibility of applying such an alloy to the manufacture of fuses. The investigation of the action of magnesium was arranged for with three aluminum alloys consisting of 6 to 8 per cent Zn.; 7 to 9 per cent Zn. and 8 to 10 per cent Zn. with additions of anywhere from 0.5 to 1 per cent Mg.; copper not necessary to be present.

The structural formation of No. 42 (see Table for its composition) exhibited the same formation as No. 44. The gamma solid solution appeared to predominate. The alloy had the slight crystalline structure that is prevalent with aluminum alloys. The slight amount of magnesium exerts a marked influence upon the crystalline formation which by comparison with alloys free from magnesium is distinctly developed in them. As chief structural constituents alpha and gamma phases occur in solid solutions the same as was considered in the preceding alloy. By means of these alloys the efficiency of the machine shops dropped to about 30 per cent.

Further investigation was carried out with an alloy called "Electron," consisting of about 95 per cent Mg. and 5 per cent Zn.

For confirmation of the stability that the old tin-rich alloy had provided, a tin-poor alloy was introduced of the following composition:

Zn., 2 to 6 per cent; Sn., 1 to 2.5 per cent; Cu., 1 to 3 per cent; Fe., maximum, 1.5 per cent.; Si., maximum, 1.05 per cent; Mg., 0.02 per cent.

In the fuse alloy the permissible shrinkage was somewhat exceeded, the zinc limit was afterwards raised from 12 to 15 per cent and lowered below 6 per cent. The magnesium remained at 1 per cent. (The author does not state what success they had with the introduction of magnesium, nor what had been their experience with electron.)

CAST-IRON IN THE LAST YEARS OF THE WAR

In the preceding section the use of cast-iron was frequently mentioned as a substitute for various metals, of which there was a scarcity, to be used in motors, steam-jet apparatus, heating construction and the finishing of fuses. In the last years of the war, to the largest extent, the use of cast-iron was a peremptory necessity.

Various articles that have been mentioned and that had formerly been made of bronze or other non-ferrous alloys, now had to be made of malleable iron castings, or steel castings, or normal iron castings, and they had to be carried out for the most part with diminished weights and often be reconstructed. The lack of good pig iron, and the poor quality of the coke in the latter part of the war led to many dissensions which made the introduction of cast-iron very difficult to carry out, not only with the means of execution provided for it earlier, but generally because the poor quality of the iron produced slowed up the productive capacity of the foundries.

The poor quality of the cast-iron was caused:

1. By the inferior coke. In peace times the sulphur in the coke amounted to from 0.8 to 1 per cent at the most; during the war the sulphur rose to double that amount, with an average of 1.5 to 1.8 per cent. Furthermore the percentage of ash was abnormally high and hence the strength and the density of the coke were much deteriorated. The latter phase caused inferior cupola practice.

2. By the scarcity of pig iron. The scarcity of iron induced in addition a great quantity of breakage, spoiled work, etc. Alloying with 80 per cent of the breakage was arranged for daily, which in part resulted in dire consequences.

By reason of the circumstances described the spoiled castings, both in the foundry and in the machine shops increased daily in contrast to what occurred during times of peace. The castings were hard, frequently as a result of edge and surface hardening or because they were hard through and through, they were chiefly unworkable or machinable only with great difficulty. Since the machine shops could not get any more good tools the continuance of the finishing proceeded with many obstacles. On top of this, other troubles cropped out such as contraction fissures so that the breakage of castings during transportation or in cleaning the sand from them, and later in the formation of piping and blisters—all appeared to be on the increase. In the pressure tests the castings developed soft spots and also broke differently.

An earlier, less known phenomenon appeared for a time, namely, the numerous so-called "reversible chill castings." The walls of the castings were hard and white within, therefore without graphite formations and, in addition, gray, therefore, normally graphitic iron. The analysis of both formations from various spots to discover the form of the carbon present gave the same chemical composition; also the total carbon was in agreement. The literature on the subject is as follows: (B. Osann, *Gies.-Zeit.*, Feb. 1, 1918, p. 33; P. K. Nielsen, *Gies.-Zeit.*, Oct. 1, 1918, pp. 299-305; Adammer, *Gies.-Zeit.*, Nov. 15, 1918, p. 385; Tech. Abteilung des Giesserei verbandes., *Gies-Zeit.*, Dec. 15, 1918, pp. 381-382; Pfalzgraf, *Gies-Zeit.*, Feb. 15, 1919, pp. 56-59; Harnecker, *St. u. E.*, Oct. 30, 1919, pp. 1307-1308.)

By means of a special method the reversible chill castings were frequently ingeniously reproduced. For the supervision of the tapping each cupola, from time to time, cast wedge-shape pieces 22 by 105 by 125 millimeters in extent. From the structure of the wedges and the view of the surface

fracture, according to the nature and extent of the hardness, the quality of the heat could be ascertained.

This sharp and practical supervision of the operations in the last years of the war was absolutely necessary. Soon after the test wedge was cast it was seized by tongs, and as soon as it was cool enough it was plunged into water and broken by blows so that the edge hardening could be inspected. Then first, the specimen from the cupola was compared with the piece obtained from the corresponding casting. It often happened that the center part of the wedge was still in a fluid state. By means of quenching in water the core remained white while the marginal edges became gray. (In the original text illustrations are given of the test pieces, but the imprint is so indistinct that the differences in the surface structure cannot be detected by inspection.)

In part the reversible chill was avoided by careful selection of the fragments, by adding manganese pig iron containing from 4 to 6 per cent Mn., by the use of the best quality of selected coke and by drying the coke in an oven to expel the moisture absorbed from the air or by exposure to bad weather.

In the course of the difficulties described previously, upon metallurgical grounds, many phenomena plainly appear that from the generality of this or that occurrence were not wholly or but little known, and their proper evaluation developed under the pressure of the exigencies of the war.

(In but two places in the text is the scarcity of aluminum referred to. As a vast amount of aluminum was consumed in the manufacture of dirigibles and airplanes, it may be that the requirements of that branch of the military service made it difficult for the foundries to secure the amount of aluminum desired for fuse construction. Although the well-known light metal "Duralumin" was used all through the war in the construction of parts of dirigibles and airplanes, nowhere is it mentioned in the text as being used for the making of fuses. In 1910 the metallurgists of Germany were better acquainted with duralumin, its manufacture, its physical properties, the methods to be pursued in its heat-treatment, and the effect upon it of aging, than anybody in this country until nearly the close of the war when American metallurgists had completed their investigations of it and had learned about its invaluable properties and the proper methods to pursue to develop them. It certainly leads up to a puzzling commentary on their repeatedly asserted super-man power and adaptability to have overlooked the possibility of using duralumin as a substitute for bronze in ever so many articles they required and so successfully carried out to continue the war.)

SUMMARY

For the construction of Diesel engines, centrifugal pumps, as well as for valves and cocks it happened with the substitutes used for the saving of metals that the results remained the same. On the other hand the durability of the metals substituted for steel in apparatus originally built of steel has not been confirmed. In the manufacture of projectile fuses the substitutes used were accompanied by far-reaching results. The possibilities of these substitutes were specified to the very limit and the kind and manner of the difficulties that were met with were overcome.

(The measures taken, the expedients resorted to, the profound knowledge of the physical properties of the useful metals exhibited and applied, offer a spectacle to the closest observers of what almost super-human skill and untiring endeavor could and did accomplish, for which there is no parallel in history.)

FERRO CERIUM

THIS interesting alloy was discussed by A. Hirsch before the American Electrochemical Society, being his second appearance on that subject before that group following the presentation nine years ago when pyrophoric alloys were more or less of a curiosity. Today ferro cerium is decidedly an item of commerce, and in Europe more than in America is replacing the match as a more convenient and safe method of lighting. The ferro cerium lighter has been nicknamed the iron match and is non-poisonous, is more compact, and where shipments are concerned has an advantage in that the ordinary match occupies a large space in comparison to its weight.

The cerium alloy manufacture derives its raw material from by-products of the gas mantle industry. The first step in the manufacture of ferro cerium is the preparation of the electrolite which is a difficult matter in view of the fifteen or twenty elements which may be contained in the raw material. The mixed chloride used as the electrolite must be freed from all substances which will interfere with the electrolysis, including sulphur, phosphorus, and silicon. There are many factors which must be kept in proper relation each to the other, and the electrolysis involved is indeed complex and difficult. The cerium in reality is an alloy of the metals in the cerium group and the electrolysis is not selective, but the cerium group appear to form an aggregate or nucleus. The alloy is soft and tough, can be cast into molds, can be cut with a strong knife, and is not pyrophoric. In many respects it is similar to lead. The cerium alloy is now melted and alloyed with iron to form a product about 30 per cent of iron, and this alloy is pyrophoric. Other special mixtures give a flame or a shower of sparks or some other similar reaction as desired, and involve the use of magnesium and zinc. Thus for miner's lamps a flame instead of a spark is desired.

The pyrophoric property would seem to depend upon the brittleness of the alloy and its low kindling point, the cerium group being exceedingly active and having a great affinity for oxygen and nitrogen. These same properties make the cerium alloy previous to its combination with iron a satisfactory deoxidizer of molten metals. With cast iron where this material had been used the castings were softer and more dense, and the formation of fine carbon was retarded. The resulting castings were sound and machined satisfactorily. Even when one-half of one per cent of cerium had been used none could be found with the finished castings, giving rise to the belief that any cerium not required as a deoxidizer is probably oxidized by contact with the air over the ladle.

The pyrophoric alloys are well established in their particular field and may become equally well known as metal scavengers.

CAUSES OF DISCOLORATION OF LIMESTONE

THE discoloration of limestone used in construction work is a serious matter and very often mars the appearance of new buildings in a comparatively short time. Leaching tests to determine the cause of this discoloration have been carried out and as a result of the work it appears that the unsightly brown stains are not due to the iron content of the cement which was previously supposed to be the probable cause of this trouble. Cement with a very high percentage of iron has produced no stain, while other cements with a small percentage of iron have given intense stains. No stains have appeared in the tests of lime mortar or slag cement. The stains, however, can be reproduced to a marked extent by allowing a solution of sodium hydroxide to leach through the limestone which indicates that the soluble alkalis in the cement are responsible for the formation of the stains.

COLORED PLASTERS

MANY decorators and artists have wrestled with the problem of securing wall plasters of desired color and texture for given purposes. The Bureau of Standards Technical News Bulletin, No. 41, reports the results of investigations which indicate that wall plaster of any desired color or texture may be made by using dyed wood fiber in the gypsum plaster. Various mixtures of colored fibers are, of course, possible and panels of the material have been submitted for further tests to the Gypsum Industries' Association. A publication on the subject is now in course of preparation.

Mineral Wax*

The Importance of Ozocerite As a Lubricant

By H. Pomeranz

THE names "machine grease" and "wagon grease" are given to the type of lubricant which is made from thickened mineral or tar oils, having the consistency of dough or a soft fat. The fast fat or hydrocarbon (paraffine cerasin) or, what is still more frequent, the free soap in the mixture is dissolved in the liquid mineral oil to form a thick solution which becomes thinly liquid at elevated temperatures and congeals on cooling to a solid mass.

During the war, the deficiency in the supply of saponifiable fats and solid hydrocarbons caused the manufacturers of lubricating greases to look for substitutes and their attention was drawn at once to ozocerite[1] which had been used hitherto for making shoe polishes. Ozocerite can be saponified to form a solid soap, which, when dissolved in petroleum in the proportion of 1 to 7 or 1 to 8, makes a solid mixture, which begins to flow at about 80° C. It is of course obvious that the real lubricant is the oil itself. The purpose of the soap, dissolved therein, is to make a composition of higher melting point, so that the liquid oil is prevented from dripping down from the bearings and going to waste, due to the friction and heating of the surfaces that are being lubricated. Hence, ozocerite does not play the part of a lubricant in the compounded grease. It is only necessary to take care that the ozocerite does not detract from the lubricating properties of the oil. Both the quality of the mineral wax and the nature and method of making the soap are the determinate factors in this respect.

The chemical properties are well-known and fully described in the literature. They need no mention here.

In the technical processing of ozocerite, there are a number of important points which require the attention of the technologist. In the first place, in determining the saponification number of the wax by means of alcoholic potash, it is observed that there is a considerable quantity of unsaponifiable residue. The saponification number is between 90 and 100. It is uncertain whether or not all, that is saponifiable, is saponified at the boiling point of the alcohol, or whether a greater proportion of the wax is converted into the soap, when saponification is accomplished by treating the melted wax at a temperature of 130° C. with an aqueous solution of the alkali.

Furthermore, if melted ozocerite is treated with concentrated alkali, a hard mass is obtained, which is difficultly soluble in mineral oil. For this reason a mixture of ozocerite wax and mineral oil is generally saponified. It is certain that the saponification is much more difficult to carry out than with pure mineral wax.

The appearance of a lubricant is an important property and the dark brown color of the ozocerite lubricant is a disadvantage. The color is due to certain dark products contained in the wax. Bleached ozocerite is a light brown material, which, however, does not give a light-colored lubricant. On the other hand, the refined wax is capable of being saponified completely. In this manner a transparent lubricant is obtained. The lubricating properties are also improved to a considerable extent.

It is very difficult to determine just how much free alkali there is present in a lubricant, made from mineral wax and oil. The ash always contains carbonate. A solution of ozocerite soap in water gives no light-colored precipitate with mercuric chloride. The more lye is used to saponify the wax, the harder the lubricant becomes. The poorly advised technologist does not pay any attention to the "lye" content of his "fat" as a general rule. He is concerned entirely with obtaining a proper consistency in his product. It is important to take particular care that too much lye is not used.

It is a question whether or not the solution of ozocerite soap in mineral oil leaves any injurious or troublesome deposits on the metal. This can only be observed by actual practical tests. The chemist has been thoroughly convinced that the use of mineral wax in a solution of mineral oil for lubricating purposes possesses very great advantages. The user of the compounded grease should not be prejudiced by its dark color which does not mean in any way that it is of an inferior quality.

*Abstracted and translated for *Scientific American Monthly* from *Kunstoffe*, 1920, 85-86.

[1]Ozocerite is a naturally occurring solid hydrocarbon of the olefine series. It is found chiefly in the Galician oil fields, where it occurs in veins at varying depths below the surface up to 250 yards. The wax is also mined in Roumania. In this country the main deposits are located in the Wasatch Mountains, about 173 miles east of Salt Lake City, Utah. The American deposits are said to be miles in length and contain a white ozocerite. The wax is also found in Colorado. The main use for ozocerite is in making ceresin. The mineral wax is subjected to a steam distillation and the distilled ceresin is compressed by hydraulic presses, melted and then treated with fuming sulfuric acid. Good ceresin can hardly be detected from bees-wax.

Ozocerite is used in the manufacture of candles, ointments, pomades and shoe blackings. It is also used to some extent in the manufacture of shining black paper and for the impregnation of certain kinds of wood in furniture manufacture.

Okonite is the residue left after the distillation of ozocerite. It forms an excellent insulating material for electrical purposes.

The use of ozocerite for lubricating purposes is a new use of this material. The properties of the wax would tend to make it appear as if considerable success could be obtained with it in this way.

A JAPANESE DISCOVERY TO FACILITATE THE HARDENING OF OILS

ONE of the most valuable discoveries in the realm of industry in recent years is that of the process for hardening liquid oils. This has various applications particularly in the manufacture of "butterless butters." One of the most useful agents in producing this hardening is the seed of the castor oil plant. However, this has the disadvantage of not keeping very well. It is of interest, therefore, to learn that a Japanese investigator, Mr. Yoshio Yanaki, has invented a method of extracting the active principle of the castor bean. This extract he terms lipase, and after extended experiment he has made public the following conclusions in regard to its action:

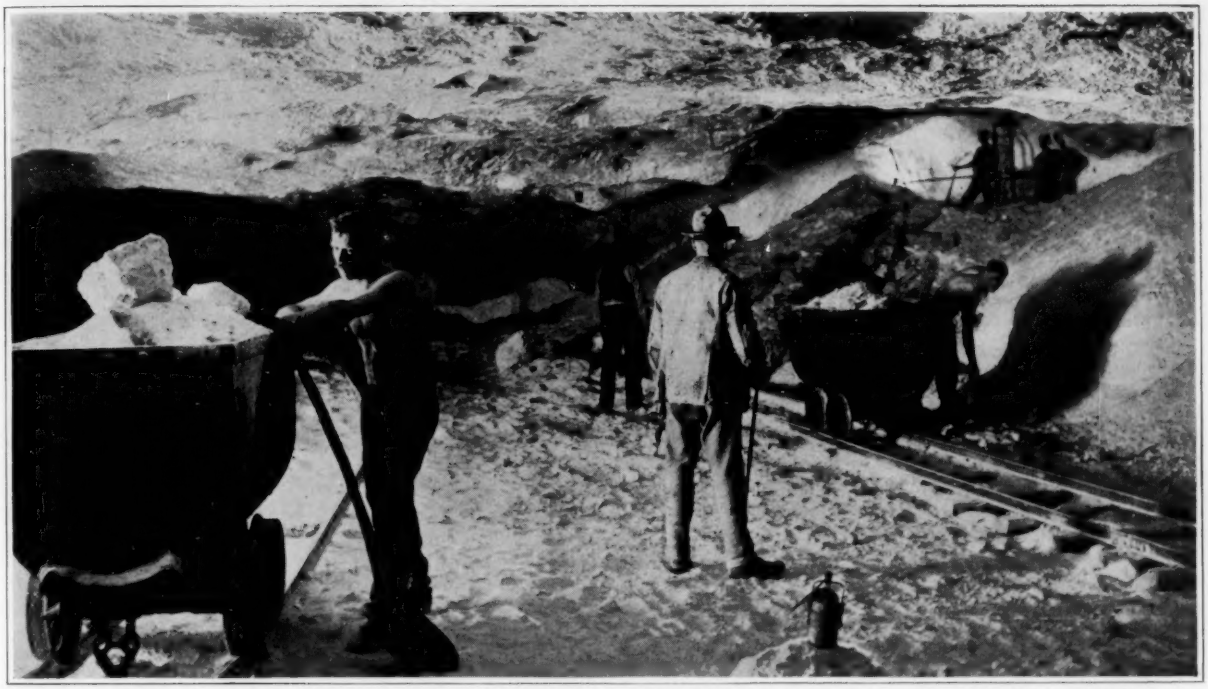
1. It is shown that lipase acts with less rapidity upon oxidized oil, prepared by insolation or by blowing air, than the raw oil. This reduction of the activity of lipase on oxidized oil is most marked in the case of drying oil, and it decreases through the classes of semi-drying and non-drying oils.

2. The slowness of the lipolysis of oxidized oil is due to the presence of some oxygen-absorbed products which are decomposable by lipase with less rapidity and which have probably a larger molecular weight owing to the absorption of oxygen.

3. The lipolysis of rancid oil is also slow, possibly on account of the presence of the oxidized products named, and of aldehydic substances, the latter injuring the activity of the lipase.

4. An oil exposed to sunlight, while protected from contact with the air, does not show any retardation of its lipolytic hydrolysis, showing that light alone produces no effect on the chemical composition of oil.

5. Heated oil which has been prepared by heating in a current of nitrogen, is more difficult of hydrolysis by lipase than the raw oil, showing that the polymerized products of glycerides are with difficulty decomposable by the enzyme.



IN THE HEART OF A POTASH MINE AT STASSFURT 2,600 FEET UNDERGROUND WHERE TEMPERATURE IS 104 DEGREES F.

German Potash Mines

The Possibility of Finding Potash Deposits in This Country

By Robert G. Skerrett

POTASH in the decades gone, when soft soap was a common commodity in the household and not the synonym for conversational blandishments, was generally got from wood ashes subjected to a simple leaching process. The very term potash is a word picture of the way in which the alkaline liquor was boiled down and concentrated. At that period in our development, potash so obtained served as an essential ingredient not only in the preparation of a laundering aid, but it figured in the manufacture of glass, powder, etc. Farmers knew that their crops were likely to be more abundant if they burned over the dry vegetation of their fields or scattered wood ashes broadcast upon their acres; but only a few husbandmen were aware that a measure of potash was indispensable to their crops and needed proportionately more by some than by others.

Potash, or potassium as it is technically named, has assumed a position of prime importance in the economy of modern life far beyond that imagined half a century ago. Not only is the stuff required in the making of glass, as a source of nitrate in the explosive industry, and as a base for cyanide so widely employed in metallurgical activities, but the sulphate and the chloride of potassium are outstanding factors in the manufacture of so-called artificial fertilizers. Finally, to a lesser degree, but likewise invaluably, potassium salts are used in dyeing, tanning, electroplating, photography, medicine and as chemical reagents for a variety of purposes.

Just what potash means to us can be gathered from the fact that up to the outbreak of the World War we imported from Germany our principal foreign source of supply, substantially a million gross tons of the salts each twelve months; and probably about 90 per cent of that material was devoted to the enriching of our cultivated soil. There are three plant foods of outstanding significance—phosphorus, nitrogen, and potassium, and the last serves to promote stalk strength and a more generous kernel filling in a growing plant. Fields denied a sufficient quantity of potash yield crops of an impaired and sometimes an unmarketable character; and the best proof of this is what happened in our farming districts when cheap potash from the mines in Prussian Saxony was cut off from us by reason of the conflict in Europe.

According to testimony given before a Congressional committee in 1919, the lack of potash had a serious effect upon our cotton, potatoes, onions, citrus fruit, and garden truck, and this largely because the commodities were deficient in that strength needful to enable them to withstand transportation and to keep them fit until sold. As one prominent farmer from the South explained it, "If there is not enough potash in the soil, I get a plant that is so sappy and tender that it won't bear transportation. And to get that plant sufficiently woody and strong to bear a long trip we have to use from 10 to 14 units of potash per acre." A unit is 20 pounds of pure potassium oxide. Time and again, peaches, strawberries, cabbages, beans, cucumbers, etc., which appeared all right when picked, would spoil or fall below standard by the time they reached a far-off city, and that in spite of refrigeration en route. Ground that would ordinarily give a crop of 80 barrels of potatoes to the acre would yield only 11 barrels and even then the tubers were not up to the usual size.

With cabbages, potatoes, and onions constituting the principal vegetable items of the dietary of the vast majority of our people, and with cotton forming the fiber for that textile used in such vast quantities by both the rich and poor of the nation, it is not hard to visualize how vital to our well-being is an abundance of low-priced potash. When the German potash deposits were first exploited sixty-odd years ago, and the mining of those beds proved a simple and fairly inexpensive operation, the agricultural world breathed freer; for the geologists proclaimed that there was enough of the alkali tucked

away there under ground to meet the demands at home and abroad for centuries to come.

These mines are located near Stassfurt, and were discovered by the Prussian Government in 1843 while boring for rock salt. For some years no attention was paid to the potash, which was brought up to the surface and cast aside. But afterwards, when it was found that potash was essential to the stimulation of crop production, the value of the neglected piles of mine waste dawned upon the Teutons; and out of that awakening developed the well-known Kali Syndikat which became all-powerful in the international distribution of those potassium salts. This was made possible by the fact that the Germans could mine, ship across the ocean, and deliver the potash at the ports of our Atlantic seaboard at an average price of from seventy to eighty cents per unit of pure potassium.

The Stassfurt salt beds, with their interposed layers of potash, were deposited there in the Quaternary Age of this globe of ours, when the present plains of northern Germany lay deep beneath a briny ocean. In the course of time, using the term in the ampler geological sense, the potash separated from the salt and was precipitated in the form of strata or pockets. This process has a great deal of significance to us in view of the fact that vast deposits of salt, likewise the relics of a sea that evaporated eons back, lie far below the ground level in a widespread area extending north and south throughout certain of our Central States. A similar condition probably exists elsewhere upon this continent of ours; but the revelations in question have been made by borings driven in search of petroleum.

In 1914, prior to hostilities, the German potash industry at Stassfurt was centered about 187 shafts, and the operating force numbered 35,000 people. It is said that quite $250,000,000 has been spent in developing the properties, and that the mines are capitalized at substantially $380,000,000. An official of the U. S. Bureau of Mines has lately visited the region and has reported that the "Stassfurt potash occurs as potassium chloride or potassium sulphate or both salts intimately mixed with salts of sodium, magnesium and lime, and contaminated with substances insoluble in water, such as ferric oxide, clay, etc. The potash salts are segregated in more or less extensive pockets throughout the salt mass. . . . The main potash region is a stratum varying from 30 to 150 feet in thickness and at a depth requiring shafts of 5,000 feet." It should be evident that the raw product is of a mixed nature, and when sold as such is valued according to the percentage or number of units of pure potassium which the stuff contains. On an average this is in the neighborhood of about twelve per cent of pure potassium.

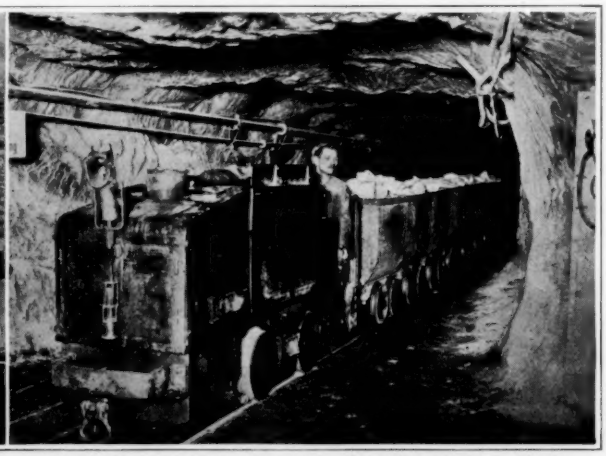
According to the German laws, each mine must have at least two shafts—one for ventilation and one for active operation. These shafts are placed from 500 to 1,000 feet apart and are connected underground. This arrangement insures that the air drawn down one shaft shall, after circulating through the several mine passages, ascend by the other shaft and thus carry off the vitiated atmosphere. The duplication of shafts further provides a means of escape for the workmen in case one of the shafts is closed by accident. It is the practice to line the shafts from top to bottom with iron, concrete or wood, according to the local needs and the availability of the materials mentioned. The shafts average about 16 feet in diameter.

As might be expected, water reaches the shafts by reason of seepage working through at the upper levels. This water drains down into sumps at the foot of the shafts, whence it is forced surfaceward by pumps. The mines are otherwise dry. Because inflammable gases appear only infrequently, the miners work by the light of bare flames, using generally a rather common type of acetylene lamp. The danger of unexpected gassing is neutralized by the action of blowers, which are kept running close to the points where the men are at work. The potash is blasted out at the face of the headings and freed in this manner in big masses. The needful holes for the explosive charges are made with electric drills and augers. The material is then broken up by the miners into good-sized lumps—using picks and heavy hammers for the purpose. At the same time the laborers separate the low-grade material from that of commercial value, and the rejected stuff is used, as occasion requires, to fill up abandoned workings.

The potash is transported from the headings by electrically-drawn trains made up of small iron cars or "buggies," and moved by rail to the elevators located in the shafts. These lifts are functioned by a mechanical contrivance that insures a nice control of their speed. There are two counter-balancing elevators in a shaft, and this interrelation has much to do with the safety of their service. Each lift is a double-deck structure which can accommodate from six to eight of the mine cars; and when working to capacity it is practicable to send to the surface between 800 to 1,000 tons of the raw potash daily by way of a single shaft.

Upon arriving above ground, the buggies, with their burdens, are run upon a platform where they are caught and held while being tipped over to effect discharge, and the crude salt drops by way of a chute into a power-driven crusher located below. From the crusher the substance may be dealt with in two ways, *i.e.*, it may be ground into bits, having a maximum dimension of a quarter of an inch, and then removed to storage awaiting shipment, or the granular material may be sent to a refinery, frequently near by. Here, trained oper-

LOADING AN ELEVATOR AT THE BOTTOM OF A SHAFT 2,500 FEET BELOW THE SURFACE



A TRAIN OF CARS OR BUGGIES LOADED WITH POTASH DRAWN BY AN ELECTRIC LOCOMOTIVE

atives sort out further the relatively high- from the low-grade potash. The latter is passed on to a grinding mill where it is mixed with raw salts, and the better grade is carried to another grinding mill and from it dropped into an elevator that transports it to the storage bin preliminary to undergoing additional treatment.

According to the report of the representative of the U. S. Bureau of Mines, who visited the European mines, analyses showed a raw salt averaging 15.6 per cent potassium oxide, while the rejected or low-grade material contained 5.8 per cent K_2O. As he explains: "The latter being added to the raw

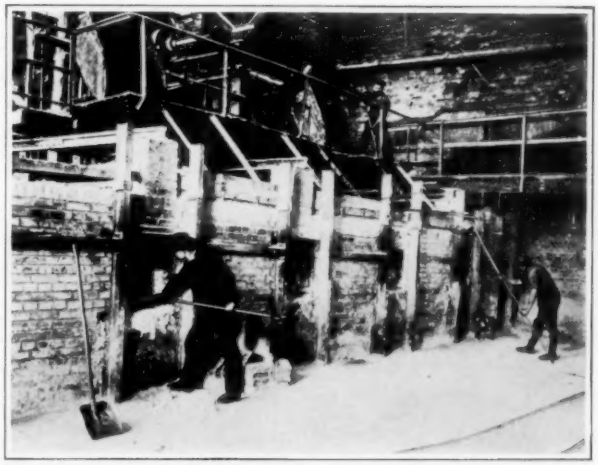
LUNCH TIME IN THE POTASH MINE

salt or 'stock kainite' brought its potash content down to 14.3 per cent, while the rich salt for the refinery was brought up to 18.6 per cent K_2O." The procedure in the refinery rests on the fact that if a solid mixture of the chlorides of potassium and sodium be brought in contact with a saturated solution of the same salts, and the combination be then heated, this treatment will induce the precipitation of a greater amount of solid sodium chloride and effect the while a further solution of a considerable percentage of potassium chloride. By properly handling thereafter the masses of brine and solid salt it is feasible to accomplish the complete recovery of the potassium chloride in any desired degree of purity.

The actual working of the process commercially is as follows, according to the authority just cited: The rich salt, so called, is fed into one end of a trough, made of sheet iron, and the boiling-hot brine enters at the other. The trough is fitted with a screw device which thoroughly stirs the mass and gradually drives the solid contents toward the opposite end of the trough and against the on-coming flow of the liquid. The trough is equipped with steam pipes which enable the temperature of the mixture to be raised as high as 230 degrees Fahrenheit. The solids in the trough or dissolver are removed by a screw-like elevator, washed, drained, and piled, until sufficiently air dried, when they are either returned to the mine to fill abandoned passages or are sold for crude sodium chloride. The washings are added to the mother liquor and used for subsequent dissolving operations. The hot brine from the trough is led to settling tanks, where the temperature falls slightly below the boiling point, and the somewhat clarified liquor is thence siphoned to the crystallizers. The residue in the settling tanks is drawn off, and drained more or less imperfectly, and the drippings are added to the mother liquor—the solids, for the most part clay, being discarded. The residue, amounting to from 6 to 8 per cent of the product as it comes from the mines, carries probably 1.5 per cent of potash. It seems that the loss of potash in the residue is but little more than 1/10 of 1 per cent.

Crystallizers are nothing more pretentious than flat iron boxes about 2 feet deep and large enough to hold approximately 6,000 gallons of the brine solution. Three days are commonly required to bring the temperature down to 50 degrees Fahrenheit. Each "pan" will yield better than 3 tons of crystallized potassium chloride; and a plant equipped with 72 crystallizers, working in three groups of 24 units, will turn out an average of 80 tons of finished salt every twenty-four hours. The mother liquor is used over and over again. The Germans have done this for 12 months' running—discarding the liquid only when it became too highly charged with magnesia and other impurities to make it serviceable. For a plant of 72 crystallizers, the coal burned, exclusive of that for the generation of electric current, has been at the rate of 13 tons per day in the refinery, and probably about 7 tons additional for general purposes in the mine, the plant, and office.

The potash deposits in Alsace, which are now in the hands of France, were only moderately exploited by the Germans prior to the World War, and they were tapped by but 17 shafts. The beds were discovered six miles northwest of Mulhouse, as recently as 1904, during exploratory borings for oil. The first mining shaft was completed in 1909 and production started in 1910. In 1913, 40,707 tons of K_2O was procured from that source. The Alsatian deposits differ notably in physical and chemical characteristics from those in Saxony. The lower layer lies at an average depth of but 1,800 feet, and constitutes a fairly continuous stratum, composed of a mixture of potassium and sodium chloride, extending over an area of upward of 77 square miles and having a mean thickness close to 11.5 feet. Twenty feet above this layer is a parallel but less extensive bed, ranging 4 feet through. Both beds are pretty commonly banded with blankets of clay, and these vary in thickness from a fraction of an inch to several inches. The upper deposit is deemed less important, and is looked upon as a reserve which can be worked later on. The volume of the two layers is estimated to be 1,350,000,000 cubic yards calculated to contain in the neighborhood of 1,500,000,000 tons



CALCINING OVENS IN WHICH THE POTASH SALTS ARE THOROUGHLY DRIED OUT

of salt or 275,000,000 tons of pure oxide of potassium—enough to meet the world's demands for possibly two centuries. The Stassfurt beds, on the other hand, are said to contain fully 2,000,000,000 metric tons of K_2O—sufficient to meet man's requirements for 2,000 years at the normal rate of consumption.

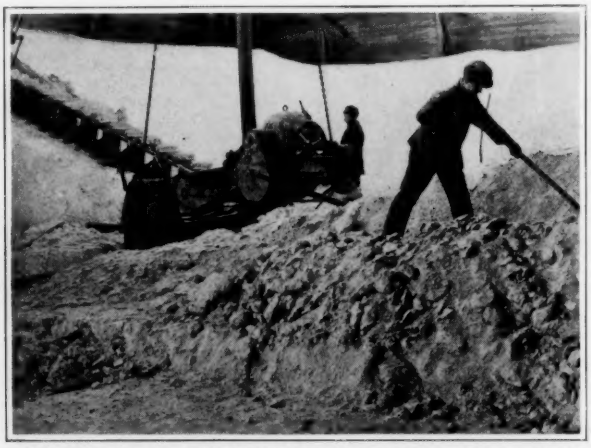
The World War brought America face to face with the possibilities of a grave potash shortage. The year before the outbreak of hostilities our importers were paying less than $90 a ton for pure potassium oxide, and before the close of 1917 domestic potash, at the plants of fertilizer manufacturers, was fetching $560 a long ton! This was derived from original sources such as alunite, the brine of certain of our highly alkaline lakes in some parts of the country, kelp, and as a by-

product of the cement industry, from wood ashes, molasses distillery waste, beet sugar refineries, etc.

By dint of very commendable enterprise and outlays totalling, so it is authoritatively declared, substantially $40,000,000, patriotic citizens embarked upon the upbuilding of a domestic potash industry. The natural salts or brines from Searles Lake, California, and the lakes in northwestern Nebraska were the principal origin of the much-desired potash obtained here after we were thrown back upon our own resources. In 1918, it was from Nebraska that we secured approximately 60 per cent of the potash produced within our borders. The section is known as the sand-hill district of Nebraska, where foliage is commonly lacking, although the soil in the valleys is fairly well cloaked with a growth of grass.

Within that region lie, in round numbers, 3,000 lakes ranging in size from modest ponds to bodies having an expanse of 600 acres. The depths of these waters run from 1 to 6 feet, and virtually 10 per cent of them are decidedly alkaline, and fully 150 of these ponds and lakes carry a high percentage of potash. The richest brines are in the bed mud and sands, and these extend downward for from 15 to 40 feet. The brines are readily obtained by pumping operations. The productive area beneath the several lakes differs greatly. That is to say, it has been found to underlie a large part of some lakes and yet, as a rule, only a small proportion of the subsurface sands have yielded brines in commercial quantities.

A very significant feature in connection with these Nebraskan fields has been the results realized from a few wells sunk in valleys more or less distant from the lakes. The quality of the brines brought to the surface have suggested that the productive region may possibly reach far beyond the lakes themselves and may even exist in localities where there are no lakes at all. Nineteen companies have operated in Nebraska, and during their activities developed capacities ranging from 3 to 200 short tons of crude potash salts daily. Inasmuch as the total quantity of potassium in these beds is rather specula-

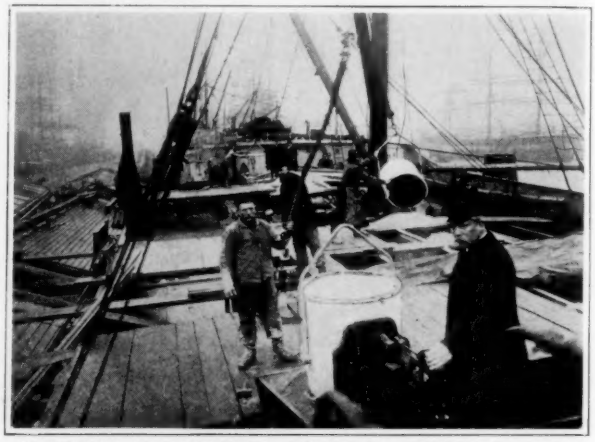


MECHANICAL CONVEYOR LOADING FREIGHT CARS WITH POTASH AT STASSFURT

tive, their potential value cannot be determined. However, one investigator has put the recoverable underground supply at 100,000 tons of K_2O.

From Searles Lake, California, we secured the second largest output of domestic potash, viewed as a single source, in 1918. The production was nearly double that of the year before; and the salts contained from 60 to 70 per cent of potassium chloride and about 15 per cent of borax. In the process of manufacture, after recourse to partial evaporation to remove a part of the associated salts, the brine is drawn off and allowed to cool—this procedure serving to precipitate the marketable potash. Estimates seem to indicate that Searles Lake contains the equivalent of 20,000,000 tons of actual potash in a saturated brine associated with soda, borax, salt, and sodium sulphate. The proportion of potash in the dried salts is about 7.2 per cent. In the German and Alsatian deposits the K_2O content ranges from 12 to 20 per cent.

Potash obtained from alunite in 1918 amounted to 6,180 short tons, containing 2,621 tons of potassium oxide, then valued at $1,276,774 at the point of shipment, *i.e.*, $4.87 per unit of K_2O. The entire output was derived from the alunite deposits in the vicinity of Marysville, Utah. Unfortunately, the quantity of alunite available for potash is not known. From such of our cement mills as are equipped with potash recovery plants we secured, in 1918, 12,652 short tons of crude potash containing 1,549 tons of K_2O. And from our blast furnaces and



WEIGHING AND LOADING A CARGO OF POTASH ON A SHIP AT HAMBURG

silicate rocks we got a matter of 310 short tons of potassium oxide. Kelp supplied us with 4,804, molasses distillery waste 3,467, beet sugar refineries 1,374, and wood ashes 673 short tons of K_2O.

What store of potash may still be hidden underground in the United States is quite unknown, but inasmuch as potash is associated in Alsace and Saxony with the salt beds of prehistoric seas, there is ample reason to believe that similar occurrences here may be indications of a like if not a greater wealth of subterranean potassium.

Doctor George Otis Smith, Director of the U. S. Geological Survey, has said: "We have been searching for potash on a very small, even a picayune, scale. For instance, there may be and probably are certain points in our underground deposits of salt where conditions were favorable for potash to be deposited. We have put down one hole in an area of 98,000 square miles, which is like taking just one look in a hay mow for a missing needle."

HARDENERS FOR CONCRETE FLOORS

MANY preparations are at present on the market for preserving concrete floors and for preventing the large amount of dust which is ordinarily associated with floors of this kind. At the request of one of the government departments, an investigation has been conducted by the U. S. Bureau of Standards, into the relative merits not only of a number of these patented preparations but also of the so-called "home treatments." For this work several panels in one of the laboratory buildings were treated with the various compounds and their condition after about two years of wear has been noted. The results, while only approximate, give a fair indication of what may be expected from treatments of this kind. The data thus obtained are combined in a mimeographed circular which the Bureau has prepared for distribution. The trade names of the various compounds have been omitted from the circular but information is given of the composition of the various substances.

Automatic Printing of Radio Messages*

Typewriter, Controlled by a Perforated Tape, Which Translates Morse Code Into Type

ONE of the recent developments in wireless telegraphy, which, as we have already announced briefly, was demonstrated by Mr. A. A. Campbell Swinton during his address on November 17 to the Royal Society of Arts, is the automatic printing of wireless messages in roman type. Several systems of printing telegraphy are in use on ordinary lines, but the ingenious method designed by Mr. F. G. Creed is, we believe, the only one that has been adapted to the printing of wireless messages. High-speed wireless reception in various forms is being used to an increasing extent, and Morse code messages are recorded by optical and mechanical methods, as well as by an instrument analogous to a phonograph; but the actual printing of the words in ordinary type on a paper strip presents obvious and very great advantages.

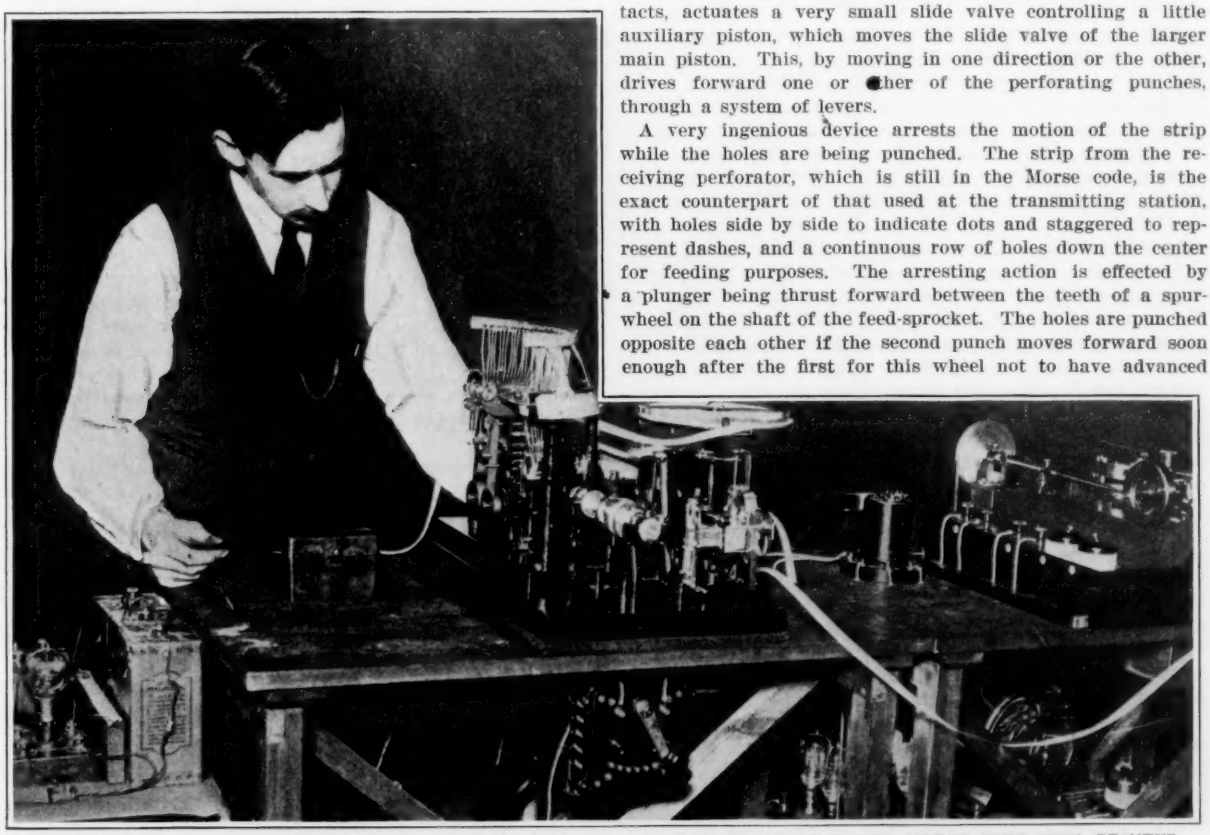
That this result has been rendered possible of achievement is mainly due to the greatly improved methods of amplification of the signals received now available, which have enabled current impulses of sufficient strength for the actuation of the necessary relays to be obtained from the minute oscillations in the receiving aerial. Briefly, the system consists in a combination of the existing printing telegraph apparatus designed by Mr. Creed with the latest arrangements of groups of thermionic valves such as those devised by Capt. L. B. Turner and other workers, who carried on important researches in this direction during the war.

In the Creed system, whether for wireless or line transmission, the message is first translated into the Morse code by punching a perforated strip of paper in an apparatus, with a typewriter keyboard, so contrived that each key perforates the strip, by a solenoid operated mechanism, with the Morse equivalent of the letter in question. This strip, exactly as in the case of automatic Wheatstone working, is passed through the transmitting instrument, which sends out current impulses in the ordinary way in the dots and dashes of the Morse code. These, in ordinary telegraphy, go direct into the line, but in wireless working they are used to actuate a special transmitting contact maker, forming the equivalent of a high-speed relay-operated Morse key. Messrs. Creed and Co. have developed several sizes of transmitters for this purpose, including one suitable for very powerful installations, worked by an electro-pneumatic relay arrangement, and capable of dealing with as much as 300 kw. This has eight sets of contacts in parallel, each breaking under a powerful air-blast.

The waves at the receiving station are picked up by a thermionic-valve receiver, and considerably amplified by a number of valves in cascade in the manner employed in connection with other methods of recording. Current impulses are thus supplied to the relay magnet, forming part of the apparatus known as the Creed receiving perforator. This is of the same form as that used in line telegraphy, and, as employed hitherto for wireless reception, is worked by compressed air, although the company is now developing an electrically driven pattern on a mechanical principle, which is simpler and more compact, and dispenses entirely with compressed air. The Creed air-engine relay used in the instrument is a very interesting piece of apparatus. The tongue of the electrical part of the relay, instead of operating electrical contacts, actuates a very small slide valve controlling a little auxiliary piston, which moves the slide valve of the larger main piston. This, by moving in one direction or the other, drives forward one or other of the perforating punches, through a system of levers.

A very ingenious device arrests the motion of the strip while the holes are being punched. The strip from the receiving perforator, which is still in the Morse code, is the exact counterpart of that used at the transmitting station, with holes side by side to indicate dots and staggered to represent dashes, and a continuous row of holes down the center for feeding purposes. The arresting action is effected by a plunger being thrust forward between the teeth of a spur-wheel on the shaft of the feed-sprocket. The holes are punched opposite each other if the second punch moves forward soon enough after the first for this wheel not to have advanced

*From *Nature* (London), Dec. 9, 1920, pp. 472-474.



AUTOMATIC TYPEWRITER OPERATED BY A PERFORATED TAPE WHICH TRANSLATES THE MORSE CODE INTO PRINTED CHARACTERS

a whole tooth pitch, so that the arresting plunger, in reaching the bottom of the space between the teeth, really brings the paper back a little way. On the other hand, if the wheel has advanced by a whole tooth pitch or more, the plunger engages in the next space, and the second perforation is advanced beyond the first. A Creed receiving perforator is seen in the center of Fig. 1.

The perforated strip is then passed on to the Creed printer. The great feature of this remarkable piece of apparatus is that it forms an automatic typewriter controlled entirely by the position of the holes in the perforated strip, and translates Morse code into printed characters. It is impossible here to do more than to indicate the general principle on which the instrument works, although it is on the perfection of the design of details that much of its success depends.

The perforated paper strip is fed past a group of spring selecting needles, ten on each side, and when it is momentarily at rest with the portion corresponding to a letter opposite the needles, a certain number, forming a pattern corresponding to the letter, protrude through the holes in the strip. Each needle which has thus advanced causes, in a way indicated later, a change in the position of one of a pack of thin steel strips or sliding valve plates. These valve plates lie between two fixed perforated plates, and are themselves perforated in such a way that the position assumed for each combination of the selector needles corresponding to a letter in Morse on the strip causes coincidence of the perforations at one point only, so that there is a clear aperture through the whole pack in a position corresponding to a letter. The bottom plate is supplied with compressed air at the moment in the cycle of operations corresponding to the printing of a letter, and each aperture in the fixed top plate communicates with a small cylinder, in which moves a piston actuating one of the type bars, through levers like those of an ordinary typewriter. Thus a letter is printed corresponding to the position of the coincidence of the valve-plate apertures.

The arrangement whereby a variable feed is given to the strip, according to the length of the letter, is combined with that for actuating the valve plates in accordance with the selection made by the needles. A reciprocating feed-rack is provided, which, when required, can gear into a spur-wheel on the same shaft as the feed-sprocket. The length of its downward travel while out of gear depends upon the point where it is arrested by the projection of one of a group of spacing levers. Normally, these levers are pushed out of the way by the selecting needles, but where neither of a pair of selecting needles advances—*i.e.* where there is a space signal—a space lever continues to stand out, thus limiting the movement of the rack to the length of the letter. A sideways movement is then given to the rack, putting it into gear and causing the perforated strip to feed forward, by exactly the length of the letter just dealt with, during its return journey. Each selecting needle, as it advances, causes a hinged piece on the corresponding valve-plate extension to move forward and to form a shoulder by the side of the feed-rack, so that the sideways movement of the feed-rack is also the actual cause of the shifting of the selected valve plates. It was mentioned above that there are only ten valve plates, whereas twenty selecting needles are provided. It is only the lower group of ten needles that controls valve plates, but the remainder are required to actuate spacing levers. Although more selecting needles may pass through the strip than those corresponding to the letter in question, only the proper number of slide valves are acted upon by the rack, on account of the limitation of its travel by the spacing levers. There are several other features, including the method of withdrawal of the selecting needles and the timing of all the various operations by means of cams, which we cannot dwell upon. The whole apparatus, including a small attached air-compressor, is driven by an electro-motor, so that no external source of compressed air is required.

Messrs. Creed and Co. have also developed an improved form of printer, in which compressed air is dispensed with, and the type characters are mounted on a circular disc and hit from behind by a little selecting hammer which is caused to stop at the part of the revolution corresponding to a letter by a circular group of selecting levers. This form of the apparatus is much more compact than the original instrument, and has a much higher printing speed; but we understand that it has not yet been adapted to wireless reception.

The Creed system with compressed-air working, as adapted to wireless reception, is capable of a speed of transmission of about 180 words a minute, which is in excess of the speed of the printer; so that, in order to obtain the full capacity, two printers would have to be installed for one receiving perforator. The improved printer, however, will be capable of keeping up with the receiver, even in its improved form, and will be able to deal with something like an increase of 50 per cent in the speed of transmission. Apart from considerations of traffic, high transmission speeds present advantages in that there is more chance of the message being completed without interruption by atmospherics or other extraneous effects. Very successful experimental working has been carried out between Cologne and the War Office station at Aldershot, and a wireless printing equipment of this kind is to be adopted between Brussels and a large station in the Congo district.

NEW STEEL ALLOY FOR PERMANENT MAGNETS

A DETAILED description of this alloy is given in the *Proceedings of the Physico-Mathematical Society of Japan* for March, 1920; a brief abstract is given in *Science Abstracts*. A favorable range of the constituents is: C, 0.4-0.8 per cent; Co, 30-40 per cent; W, 5-9 per cent; Cr, 1.5-3 per cent. Its best quenching temperature is 950° C., and the best quenching bath a heavy oil. The steel requires almost no heat treatment in order to be used as a permanent magnet in electrical instruments. The values found for the coercive force varied from 215 to 257, or about three times greater than that of the best tungsten steel hitherto known. Its residual magnetism is also greater than that of tungsten steel. The Brinnell hardness numbers for the alloy were 444 (annealed), and 652 (quenched); the corresponding Shore numbers were 38 and 55. The hysteresis loss was 909,000 ergs (best tungsten steel 209,000). When artificially aged by heating in boiling water for 40 hours, there was a slight increase in residual magnetism, this having taken place in the first three hours' heating. Repeated shocks by fall caused the residual magnetism to decrease from 854 to 800, after 850 falls of 1 meter upon a concrete floor. The residual magnetism increases rapidly with the dimension ratio up to the ratio 20, after which it is unaffected by the ratio. The steel when quenched is mechanically very hard, and has a very fine microstructure. It is specially suited for short bar magnets.

STORED ELECTRIC HEAT FOR A SPINNING MILL

A Swiss spinning mill which has its own waterpower is also connected to the Zurich Canton Electricity Works so that it can obtain current at night on very favorable terms. Hence the old steam heating installation has been converted for electric heating and a hot water accumulator has been added. Steam is generated in the boiler by an electric coil. When the maximum permissible temperature is attained, say, at 4:30 A. M., the boiler is automatically cut off from the circulating system, so that it shall not give out its heat too soon, and the circulating system is fed during the rest of the night direct from the heating coil, so that rooms are kept warm. When the night current is automatically cut off and the working day begins, the boiler is reconnected to the circulating system, and commences to give out its stored-up heat.—F. Rutgers, *Bulletin, Schweiz. Elektrotechnischer Verein*, July, 1920. Abstracted through *The Technical Review*.

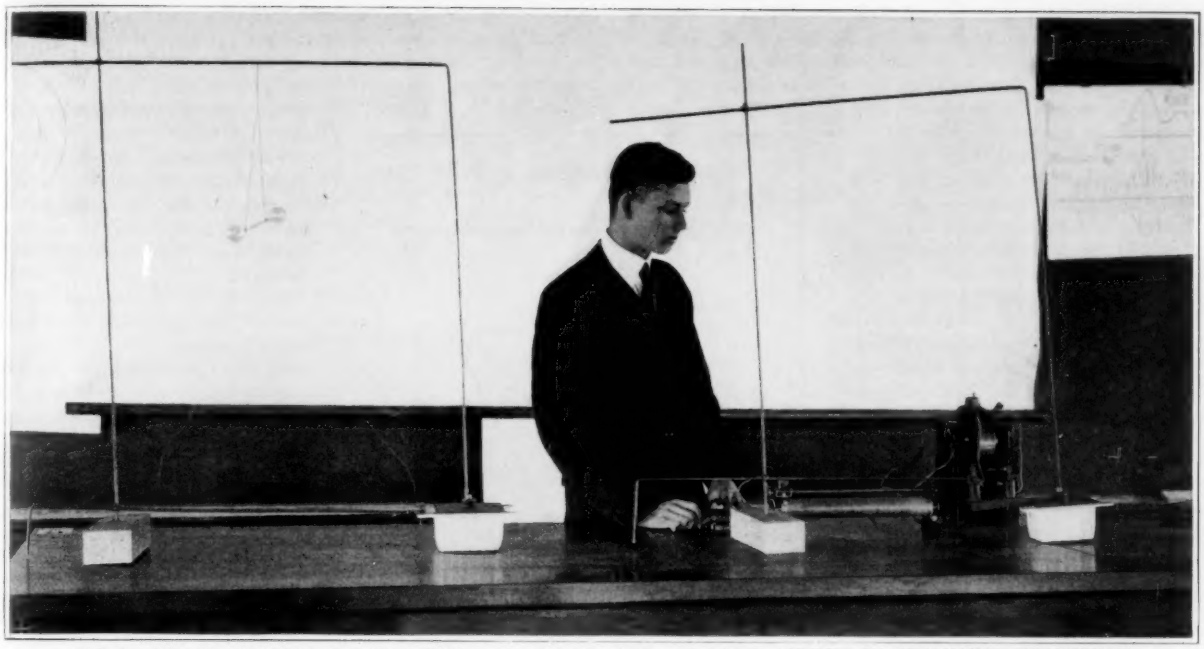


FIG. 1. CIRCUIT PRODUCING RADIO WAVES (*AT RIGHT*) AND (*AT LEFT*) CIRCUIT IN RESONANCE THEREWITH

Radio Communication

Elementary Explanation of the Principles of Radio Telegraphy and Telephony

By J. H. Dellinger, Physicist

Despite the fact that radio telegraphy and telephony is now an old story and although countless youthful experimenters throughout this land are familiar with the principles underlying these forms of communication, there are many men to whom the transmission of messages through space is still a deep mystery. For this reason we believe that the following paper by J. H. Dellinger of the staff of the U. S. Bureau of Standards, which was recently delivered as a popular lecture and which gives a very elementary explanation of radio communication will be welcomed by many of our readers.—EDITOR.

MESSAGES are now sent without wires between any points on the earth's surface, in the air, or under the ocean. It is possible to sit down to the telephone in your house and talk to persons not only in distant cities but to persons sailing on the ocean or flying in airplanes. The principles which make wireless or radio telephony possible are really not difficult to grasp. While a great deal of mystery has been made of radio, as a matter of fact everything about it is simply a part of principles and ideas well known to science. Since the results achieved in wireless communication are somewhat striking, the newspapers lose no opportunity to use them to incite the wonder of people.

The radio telephone is not a particular instrument; that is, when you talk into a radio telephone you do not necessarily talk into anything different from the ordinary telephone on your desk. Sometimes people talk of a radio telegraph or even of a radio, indicating an idea that some particular, wonderful kind of apparatus accomplishes the feat of communicating from one place to another without wires. As a matter of fact, radio is a system or method involving a great many instruments and appliances. Some of the instruments are very interesting indeed, among them being the electron tube of which more will be said later.

The history of radio is all comprised within our own lifetime, and has been a steady conquest of distance. The rising line in Fig. 2 shows for any year since 1897 the greatest distance which had then been obtained by radio communication. It increased from three-fourths of a mile the first year, when Marconi performed his startling first experiment, to thirty-four miles the next year across the English channel, and so the distance has steadily risen. Last year the distance finally rose to 12,000 miles. This is the limit, since 12,000 miles is half way round the earth. We cannot communicate any further than this unless we exchange signals with other planets. To be sure the newspapers had us communicating with Mars in April, 1920, but this must be discounted.

The word "radio" suggests its own explanation. It means to radiate. Radio communication is carried on by means of waves which are radiated from one place and received at another. These radiated waves are electric waves but they have all the characteristics of wave motion possessed by other kinds of waves, such as sound waves or even the simple waves produced in water when a pebble is thrown into a pond. Much can be learned about the way radio waves act by watching the spreading out in circular rings of ripples on water. Other simple types of waves are also produced by ordinary mechanical means. One can easily produce waves on a rope by shaking the free end. This illustrates that a wave always consists of some sort of to-and-fro motion. Waves can be slow or fast and of different wave length. We cannot see electric waves, as we see ripples or the waves on a rope, but there is nothing special or mysterious about them. We cannot see sound waves. If a tuning fork is struck, it gives off sound waves, which, starting at the tuning fork, travel out

into the air in all directions like the ripples referred to.

Sound waves are produced by the motion of the metal prong of the tuning fork. As the prong moves back and forth it causes the air next to it to move back and forth. This motion is handed on to the surrounding air and so moves out to a great distance in the air just as the ripple on the pond spreads out. The slight to-and-fro- motion of the air spreading out in this manner is called a sound wave.

Electric waves also consist of a certain kind of to-and-fro motion. Just as the motion of the tuning fork causes alternating pressure in the surrounding air, similarly whenever an alternating electric current flows in an electric circuit the to-and-fro motion of the current causes alternating electric pressure in the space next to the wire. This to-and-fro or alternating electric pressure in the space surrounding the wire affects the surrounding space and spreads out in exactly the same way as a sound wave in air. Fig. 1 shows a simple electric circuit (rectangle of wire) arranged so that an alternating current is produced in the wire. When the key is pressed a spark occurs at the spark gap, which lets one know that an electric current is flowing. It is to be noted that this apparatus produces at the same time sound waves, light waves, and electric waves. The electric waves are also called radio waves, and it is by means of them that radio communication is carried on.

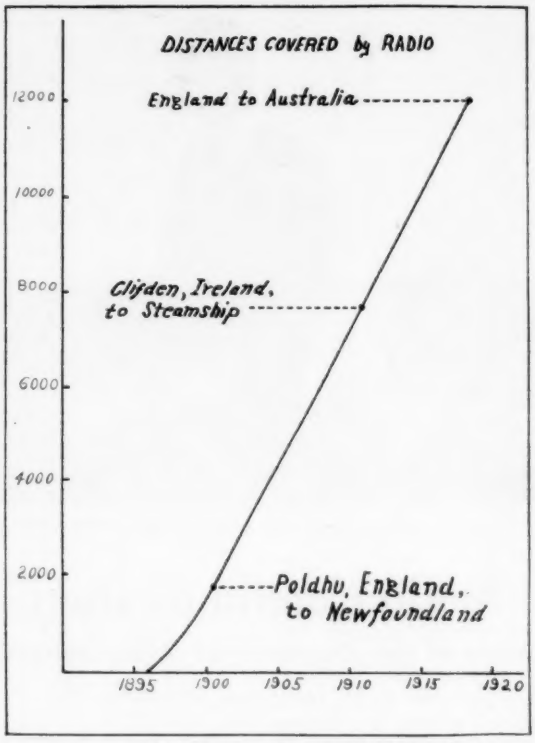


FIG. 2. PROGRESS OF LONG DISTANCE RADIO TRANSMISSION

It is an interesting fact that radio waves are really of the same kind as light waves. We are all familiar with light waves, and it should help to make radio waves less mysterious to know that they are both electric waves. The difference between light and radio waves is the frequency of alternation. Thus electric waves are much more common things than is sometimes supposed. Electric waves are used for many purposes, their use depending on the frequency of the waves. This is shown by the following table showing the frequencies of the various kinds of electric waves. By frequency is meant the number of vibrations per second or the number of to-and-fro alternations of the electric pressure as the wave travels out through space.

Waves Produced by	Vibrations per Second
Commercial Alternating currents	25 to 500
Telephone Currents	16 to 3,000
Radio	10,000 to 30,000,000
Heat and Light	3,000,000,000,000 to 3,000,000,000,000,000
X-Ray	3,000,000,000,000,000,000

All of these waves travel at the same speed. These electric waves are of an entirely different nature from sound waves. Sound waves are not at all electrical; they consist of actual to-and-fro motions of the air particles and travel with a speed of about 1,000 feet per second. The speed at which electric waves travel is much greater than this; it is so great that the passage of any kind of electric wave is practically instantaneous. The various kinds of electric waves shown in the table are much alike in many ways but they have some characteristic differences.

The waves are radiated and spread out more effectively the higher the frequency. The ordinary low frequencies used in the alternating currents which light our houses alternate very slowly. Such waves travel readily along wires. In order to get a wave which will travel effectively through space, higher frequencies must be used; that is why the frequencies shown in the table for radio communication make a large number of vibrations per second.

It is to be noted that these frequencies are not, however, as high as the frequencies of light waves. Light waves travel in straight lines, which is one of their characteristic differences from the low-frequency waves of alternating-current power, which follow along wires. Radio waves are intermediate in character between the two, and can travel in straight lines and also travel along conducting wires. Radio waves are different from light waves also in that they go through ordinary walls of buildings and other obstacles which are opaque to light.

We are now ready to consider how an electric wave may be produced.

Whenever there is an electric circuit in which alternating current is flowing an electric wave starts out just as a sound wave starts out from a vibrating tuning fork. A powerful sound can be produced by using a very large tuning fork, and similarly a powerful electric wave is produced by making some part of the electric circuit large in dimensions. The antennas used in radio work, as is well known, often consist of long conductors supported on very high towers. A mechanism for producing a radio wave, therefore, is simply an enlarged or extended portion of an electric circuit in which an alternating current is made to flow. In the space near the antenna, alternations of electric pressure are produced just as alternations of air pressure are produced around a tuning fork. At any instant the electrical condition of the space around an antenna which is sending out radio waves could be shown by a diagram such as Fig. 5. The arrow on the line extending between the antenna and ground indicates that the electric pressure at a particular moment is in the direction indicated. When the current changes in direction, the direction of this electric pressure will be reversed and the electric pressure already mentioned will have handed

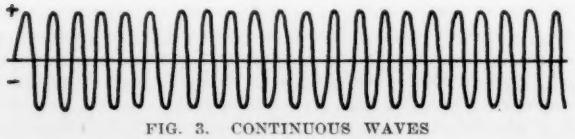


FIG. 3. CONTINUOUS WAVES

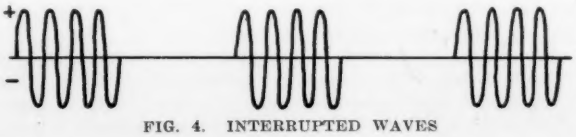


FIG. 4. INTERRUPTED WAVES

on its effect to the surrounding space. Thus the effect of an electric pressure is handed on and spreads out through space, the direction of this pressure at any point constantly alternating as the direction of the current in the antenna producing it alternates. Lines of electric pressure alternating in direction are thus constantly spreading out from the antenna just as the ripples spread out on a pond. Something very similar to the ripples would be seen if, in some way, the alternations of electric pressure could be made visible and a person were to look down from above upon the antenna and the space around it. The waves of electric pressure spreading out and successively alternating in direction would look something like the lines shown in the upper part of Fig. 5. The waves spread out in all directions and go to great distances.

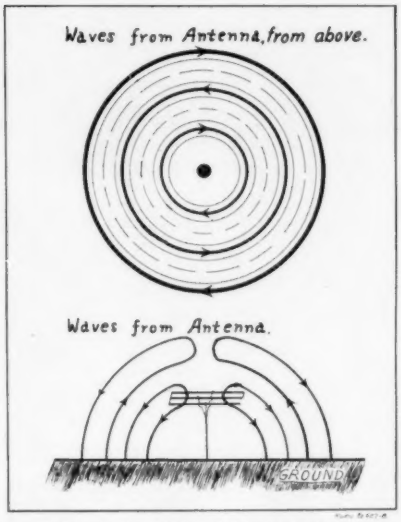


FIG. 5. PRODUCTION OF WAVES AROUND AN ANTENNA

Now think of what is happening at a distance from the antenna. As the wave passes any point there is an alternation of electric pressure going on continuously at that point. The alternating electric pressure or wave action at that point could be illustrated by the wavy line of Fig. 3. The portions of the wave above the horizontal line correspond to the electric pressure in one direction, and the portions below correspond to the electric pressure in the other direction. This can be understood by thinking again of the ripple on the water. Suppose there is a cork or other floating object on the surface of the water at a distance from the place where the ripple starts. As the ripple takes place, the cork rises and falls, partaking of the to-and-fro motion of the surface of the water. Or consider the sound wave. As the sound wave passes out through the air, it will set in vibration any object which is capable of taking up the motion. Suppose, for instance, that a sound wave produced by a tuning fork passes a second tuning fork which is in tune with it, that is, having the same natural pitch or frequency of vibration as the first tuning fork. The to-and-fro motion of the air will start the second tuning fork into motion. This can be readily shown with two tuning forks, striking one of the forks, thus producing a sound wave. It can be proved that the second tuning fork is set into vibration by grasping the first with the hand so as to prevent its further motion. A sound from the second one can then be heard. The same thing is sometimes illustrated in a room. If a note is sung or produced on some instrument, a response may be heard from one of the strings of the piano or from a loose portion of a chandelier or other resonant object in the room.

An electric wave can produce an effect at a distance in just the same manner. In any electric curcuit the moving wave of electric pressure can produce an electric current alternating with the same frequency as the wave. This is also readily illustrated just as the effect of one tuning fork on another was illustrated. Taking the same electric circuit with its spark gap, which was shown before, and allowing an alternating current to flow in it, it sends out an electric wave which can act on another electric circuit entirely disconnected from the first. In Fig. 1 the response in the second circuit when a current flows in the first circuit is shown by the fact that the indicating tube in the second circuit lights up when a current flows in the first circuit.

In order that this may take place, the second circuit must be in tune with the first. That is, it must be arranged to respond to the frequency of alternation possessed by the first circuit and the wave which it sends out. This is just like what happens with the two tuning forks and the sound wave. The second tuning fork does not respond to the wave from the first unless the two are in tune. This can be shown by placing a bit of wax on one of the prongs of the second tuning fork, changing the pitch of that fork. When the first tuning fork is struck under these conditions it can readily be demonstrated that the second fork does not respond. In the same way the electrical arrangements in the receiving circuit which are used to receive radio waves must be such that the receiving circuit is electrically in tune with the radio wave. By this means the radio receiving circuit can pick out the particular wave which it is desired to receive and not be affected by other waves. This is fortunate because otherwise the interference between different radio messages would be hopeless. It would be just as though every sound wave which passed through the air set absolutely everything which it touched into vibration.

As has been mentioned the frequency of alternation of radio waves is very high, so high, in fact, that a sound wave of such frequencies could not be heard. Suppose, for instance, that an ordinary telephone receiver was placed in the circuit which is receiving a radio wave. The electric currents of the same frequency as the wave frequency tend to cause motions of the telephone receiver diaphragm. These motions are, however, of such great frequency that no audible sound is produced. In order to permit the radio wave to be received and transformed into a sound it is therefore neces-

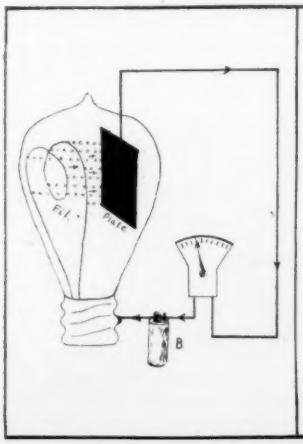


FIG. 6. USING ELECTRON FLOW FROM HOT FILAMENT

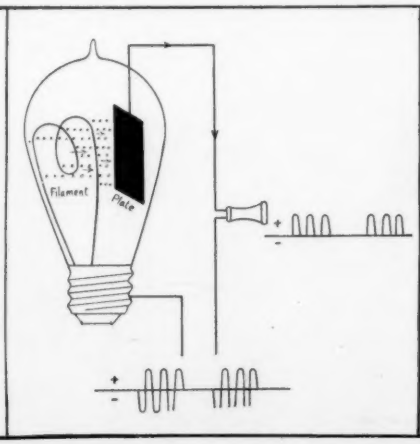


FIG. 7. USE OF ELECTRON FLOW APPARATUS AS AN ELECTRIC VALVE

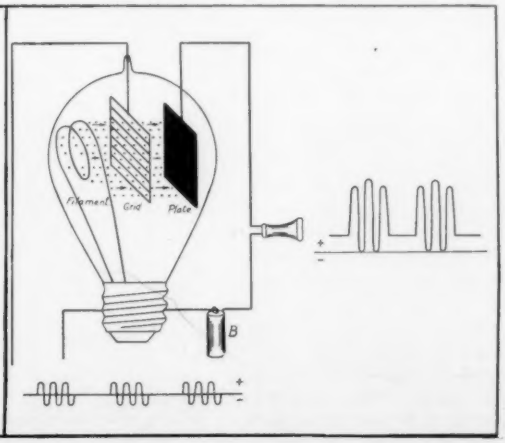


FIG. 8. ELECTRON TUBE FITTED WITH A GRID BETWEEN THE FILAMENT AND PLATE

sary to break up the radio wave in some manner. This is done in radio telegraphy by interrupting the wave completely so that it consists not of a single regular series of alternations but of a succession of groups of such alternations, that is, instead of the continuous wave shown in Fig. 3 we use the interrupted wave or group of waves illustrated in Fig. 4. The frequency of the interruptions or of the groups of waves is the frequency which can be heard.

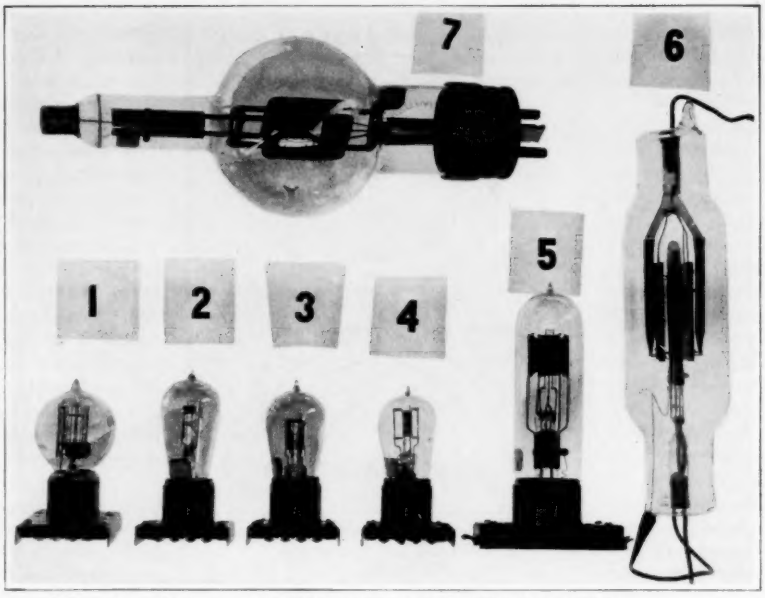


FIG. 9. VARIOUS TYPES OF ELECTRON TUBES

There is another thing that is to be taken into account before it becomes possible to translate the received radio current into a sound that can be heard. When one of the groups of alternations shown in Fig. 8 acts on the telephone receiver it causes no motion of the diaphragm because each variation of the current in one direction is immediately followed by the current in the opposite direction so that the resulting effect of the group of waves upon the telephone receiver diaphragm is no motion at all. It is therefore necessary, in order to convert the current into a sound, to use something else with the telephone receiver. This something else must be such as to make the current flow through the telephone receiver in only one direction. It must allow the electric current to flow through it in one direction and stop current which tries to flow through it in the opposite direction; that is, it must be some sort of electric valve. The effect of such an electric valve may perhaps be understood more clearly by taking a sheet of paper and placing it upon Fig. 4 so as to block out the lower half of the waves shown. This leaves only the upper halves of the little groups of waves and this is exactly what the electric valve does. It results that successive impulses of current flow through the telephone receiver and all of these tiny impulses in any one group add their effects together and produce a motion out of the telephone diaphragm. The interval between one group and the next permits the motion of the telephone diaphragm to subside and this intermittent motion causes what is heard as a note in the receiver.

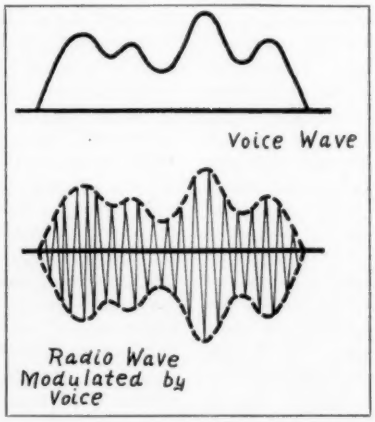


FIG. 10. VOICE WAVE CARRIED BY RADIO WAVES

A number of devices are used to perform the electric valve action which has been mentioned. The most interesting and most effective device of this kind is the electron tube. The electron tube is a very simple device which looks more like an ordinary incandescent lamp bulb than anything else. Your attention is particularly invited to the principles upon which it operates since this is the most important of the apparatus used in radio. While experimenting in the development of the incandescent lamp Edison made the discovery that an electric current could be made to flow in the empty space inside the bulb near the hot filament. If a middle plate is placed inside of an incandescent lamp bulb near the filament (Fig. 6) and if by means of a wire through the glass this middle plate is connected by wire through a battery and an indicating instrument to the filament, a current will flow as indicated by the instrument. A current is flowing in the wire and also flowing across the empty space between the filament and the plate. By much patient scientific research, scientists have found out that this current taking place in the lamp consists of the flow of a stream of very small electric particles called electrons. These electrons are shot out into the surrounding space in all directions by the hot filament. The electrons may be said to fill the bulb like a vapor. They move at random in all directions unless there is an electric force to make them move in some particular direction. The battery connected in the circuit outside the bulb supplies an electric force which acts between the filament and plate and makes the electrons move from the filament to the plate. If the battery is disconnected, there is no current, and as many electrons as strike the plate fall off again into the bulb. The current depends on the number and speed of the electrons. The battery is what gives them their speed in the direction filament to plate. The battery performs much the same action as a steam pump would if the bulb were a room into and out of which steam pipes were connected. If the pump were disconnected, there would be no flow of steam and when the pump is connected, steam is made to flow into and out of the room and through the pipe.

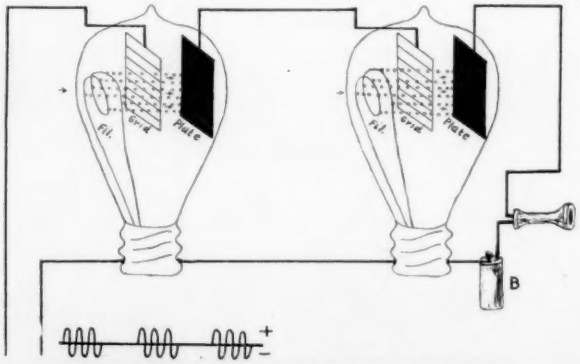


FIG. 11. THE PRINCIPLE OF THE AMPLIFIER

The point of all this is that the electron flow in the bulb has a valve action. The electrons are emitted by the very hot filament and can be

made to flow toward the plate by connecting a battery in the proper direction. If the connections of the battery are reversed, however, no current will flow because there is no such emission of electrons from the plate, which is cold, the electric force produced by the battery in this case has nothing to work on and can do nothing except prevent the flow of electrons out of the filament to the plate. It should be clearly understood before going further that the action of the electron tube thus depends upon the fact that an electric force can be applied in one direction which causes an electric current from the filament to the plate, but that if this electric force is reversed no current flows. The device gives exactly the electric valve action needed in order to make the incoming radio signals produce sound in a telephone receiver. Suppose that the bulb shown in Fig. 6 is connected up to a radio receiving circuit in place of the battery. Suppose also that the indicating instrument is replaced by a telephone receiver. This is shown in Fig. 7. The pulses of current in the radio receiving circuit similar to those of Fig. 4 produce electric force inside the bulb between the filament and plate which alternates in direction just as the pulses of current do. On account of the valve action, current can flow through the bulb only in one direction and consequently the pulses of electric force in one direction only are effective. As a result, pulses of current flow through the telephone receiver in groups, the pulses being all in one direction. This causes a note in the telephone receiver, as already explained.

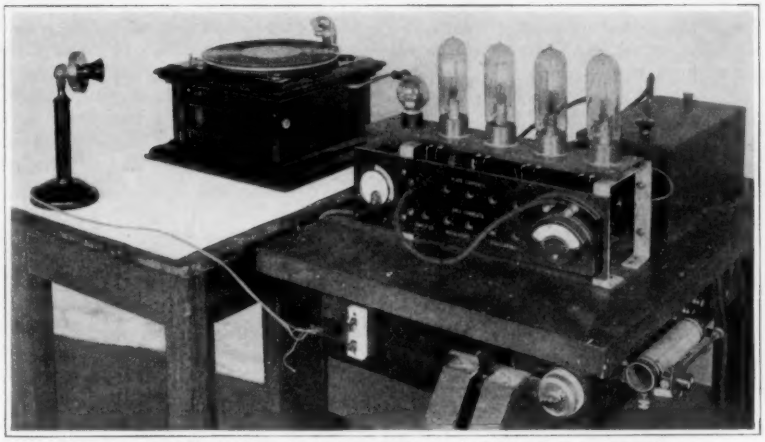


FIG. 12. PHONOGRAPH PLAYING INTO A RADIO TRANSMITTING SET

It might seem that these small electric particles, called electrons, are very remote from any practical use. The study of electrons has in fact been advanced by purely scientific research not at all connected with any applications. By means of the electron tube, however, very practicable use indeed is made of electrons and their importance is recognized commercially. Scientific research work which has been done in this connection has revolutionized radio and provided a means for great improvements in ordinary wire telephony and also in other uses of electricity.

An improvement in this electron device can be made which very greatly extends its power and usefulness. As shown in Fig. 8 a grid of very fine wire can be placed in the tube between the filament and the plate. The grid is placed closer to the filament than to the plate. The electrons which are emitted by the filament can move freely between the grid wires. If by means of a battery or something else an electric force is established between the filament and the grid, this electric force causes electrons to move away from the filament toward the plate and since the grid is placed much closer to the filament the electric force makes the electrons move much faster than the same electric force between the filament and plate would. Very few of the electrons are taken by the grid, and a very small current thus goes through the wire connected to the grid. Thus a very small current to the grid controls the flow of a much larger current to the plate. Hence a larger current can be taken out of the tube than is put into it. A small electric force acts between grid and filament causing a large electron flow from filament to plate. There results a relatively large flow of current in the apparatus connected outside the tube between the plate and filament. This device is commonly called an electron tube. It magnifies or amplifies electric currents. It accomplishes the control of a large amount of power by a small power. This is just the same

FIG. 13. PORTABLE RADIO RECEIVING OUTFIT WITH CASE OPEN

FIG. 14. LOUD-SPEAKING OUTFIT RECEIVING CALLS FROM SHIPS AT SEA

FIG. 15. RECEIVING OUTFIT IN A CASE ONE FOOT SQUARE

thing that a gun does—pressing the trigger several times in a repeating pistol is like the action of the tube with successive pulses of electric force. The grid corresponds to the trigger and the plate to the gun barrel.

A number of forms of electron tubes as used today are shown in Fig. 9. They are used to receive radio waves and make signals just as the simpler device shown in Fig. 6 does, and they amplify the signal as well as make it audible. This is suggested to the mind by the larger wave shown with the telephone receiver in Fig. 7 and Fig. 8. On account of the control of the plate current by a smaller grid current, the electron tube makes possible very wonderful feats. It is worth while to note the explanation quite carefully as it will be shown presently that this explanation contains all the most important features of radio telephony.

It is perfectly possible and quite easy to take the magnified output from an electron tube and pass it into a second electron tube, using that to make a still further amplification of the current. Using one tube after another in this way, we obtain what is called an amplifier. Two tubes joined together in this way are shown in Fig. 11 and the process can be repeated several times using a number of tubes. The current is increased by each tube and handed on to the next without any change or distortion of the current even though it passes through several stages.

The amplifier is of the greatest importance both in radio and in long-distance wire telephony. It reduces the amount of power that must be used in a radio transmitting station because when an amplifier is used in a receiving station, signals can be received which are far too feeble to be received without an amplifier. By means of amplifiers to which were connected loud-speaking telephones, demonstrations have been given in which an airplane more than a mile in the air addressed large crowds on the streets of New York. One of President Wilson's speeches in the West was spoken into a telephone apparatus and amplifiers were used to make it fully audible to all persons in a very large crowd. The large announcers used in railway stations now make use of amplifiers. By means of amplifiers, submarine vessels can receive radio messages when entirely submerged. It is an interesting fact that an amplifier can be made so powerful that no input current at all is required. This does not mean that it is a perpetual motion machine, because the power to operate it must be supplied by the battery that is connected in the plate circuit of the tubes. It does mean, however, that the electron tube can be used to generate alternating currents as well as to receive and to amplify them.

Thus far we have discussed only signals such as are used in telegraphy. The voice can be transmitted and received by the same apparatus and principles. The human voice produces sound waves which cause air vibrations of an irregular character. Such a wave may be roughly illustrated as in Fig. 10. The variations in the wave are much slower than the alternations of current used in radio. It is possible to make a radio wave carry a voice wave and when this voice-modulated wave is received it can be passed through a telephone receiver and the voice heard just as the radio telegraph signals are heard. The principle simply is that instead of breaking up the continuous wave of Fig. 3 by interrupting it, as in Fig. 4, it is caused to vary in accordance with the voice wave and these variations can be made audible. The way in which the voice wave is superimposed upon the radio wave is illustrated in Fig. 10. The alternations of the radio wave are shown by the full lines, and the dotted boundary lines show that the intensity of the wave has been made to vary in accordance with the sound wave produced by the voice. This wave can be received in exactly the same way as any wave in ordinary radio telegraphy—no special apparatus is required for receiving radio telephony. The voice at the transmitting station is heard very clearly. It can be made as loud as desired at the receiving station just as radio telegraph signals can be by the use of amplifiers.

The radio wave is really modulated or molded just as a phonograph record is molded by a sound wave. The means by which this modulation is accomplished is the electron tube. If in Fig. 8 the telephone receiver is replaced by any kind of generator of radio current, then if a person speaks into a telephone transmitter connected between the grid and filament of the tube the variations caused by the sound of the person's voice are impressed upon the radio current in the plate circuit and a modulated radio wave as in Fig. 16 is produced.

A small radio telephone transmitting outfit which is used for demonstration and experimental purposes at the Bureau of Standards is shown in Fig. 12. Music is readily transmitted out into space by playing the music into a telpehone transmitter. A phonograph may be used as shown in Fig. 12. The telephone transmitter is connected to the radio telephone apparatus upon which the electron tubes may be seen.

A receiving outfit usable in demonstrations is shown in Fig. 14. The receiving circuit or antenna is entirely contained within the frame shown in the picture, and electron tube used as a detector and amplifier and the loud-speaking telephone receiver are all visible. A much more compact radio receiving outfit is shown in Figs 13 and 15. The box encloses the electron tubes, the receiving antenna and all necessary apparatus connected to the horn which projects from the box. This is actually a satisfactory receiving set for demonstration and other purposes. It suggests the possibilities of the future. Radio sets of small enough size to use in any ordinary room or in moving vehicles can easily be made even now.

By means of electron tubes, radio telephone messages were successfully transmitted five years ago over a distance of 5,000 miles. Concerts are already being sent out by radio and are receivable by anyone who has an ordinary receiving set. This result has been accomplished by patient research, scientific study and progressive engineering. In Bellamy's "Looking Backward," describing conditions in the year 2,000, an arrangement is described by which people receive music in their houses any time desired by simply connecting a certain electrical instrument. In this particular the dreams of the prophet have been anticipated by eighty years.

USE OF BARBED WIRE AS A PROTECTION AGAINST SURGES

R. NAGEL, writing in *Archiv f. Elektrot*, Jan. 8, 1920, proposes to utilize the glow discharge as a protective device against surges. A loss of energy takes place through the discharge, and this can be accentuated by providing sharp points, from which this discharge can the more easily take place.

It is the opinion of the author that commercial barbed wire might serve the purpose of providing a number of sharp points along a conductor in an easily manufactured form. He describes various tests that have been carried out with a view to determining the most convenient conditions under which the barbed wire should be installed. Various types of barbed wire are on the market, but any material serves. It would be well not to use ungalvanized iron, seeing that the spikes would be liable to rust, and in this way the tips from which the discharge takes place would eventually lose their sharpness and become ineffective. If the whole of the transmission line were made of barbed wire, this would be effective, but it is an unnecessary expense. It would be sufficient to insert lengths of barbed wire in the transmission lines for short distances in the neighborhood of every substation. If the atmospheric conditions are such that it is known that there is a danger zone over a given stretch of the line, as, for instance, over an exposed mountainous stretch, it might be well to use barbed wire in such places. The paper contains the results of tests which have been made with a view to determining the effect produced and the amount of energy that can be dissipated in this way.—*Science Abstracts.*

A New Electric Battery

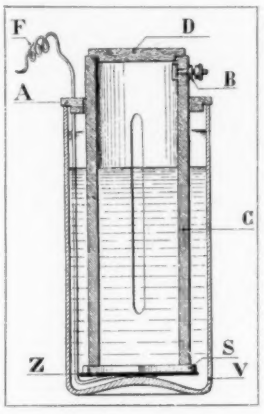
A Cell for Which Remarkable Advantages Are Claimed

A FRENCH inventor named Féry has constructed a new battery for which the following advantages are claimed:

1. *It never contains corrosive salts* whether used in continuous or interrupted service because of the fact that the superficial solution is poor in mineral salts and rich in ammonia.

2. *The salts which are formed by long operation of the battery are deposited in the middle portion of the vessel,* thus leaving the zinc as well as the surface of the liquid perfectly clean.

3. *There is complete utilization of the sheet of zinc* by reason of the circumstance that it always remains clean and wear and tear occurs in a uniform manner. The zinc is not used up in an open circuit, since it is placed at the bottom of the vessel in a solution of chloride of zinc, so that the oxygen and the ammonia are unable to reach it. Even the presence of foreign metals in contact with it (*e.g.*, the solder and the copper wire) do not occasion local wear, since the latter metals are at once covered with a protective layer of zinc. Finally, when the zinc is used up it is only necessary to renew it and also the ammoniacal solution in order to have a new battery. The ammoniacal solution, indeed, can be used again after being filtered, since the ammonium hydrochlorate which it contains remains unaltered.



THE FÉRY ELECTRIC BATTERY

Since a battery made in this manner is much cheaper than the ordinary one which employs manganese dioxide, it seems destined to take the place of the latter.

Writing in *La Nature* (Paris) for Sept. 18, 1920, M. A. Troller says:

Since the depolarizing agents usually employed in batteries are expensive, it has long been endeavored to find some method of substituting the oxygen of the air, which is obtainable everywhere gratis, but no one succeeded in this until M. Féry accomplished the feat during the war. He reasoned as follows:

A battery generally consists of two vertical electrodes immersed in an exciting liquid. It is at the surface of the liquid that the oxygen which it is desired to use as depolarizing agent, is dissolved. But the exciting solution being exposed to air upon its surface, is rapidly deprived of its oxygen by the highly oxidizable metal, zinc. Zinc oxide, moreover, dissolves readily in hydrochlorate of ammonia, which is the exciting liquid most often employed.

To remedy these defects M. Féry arranges the zinc in the form of a horizontal plate at the bottom of the cell element. The positive electrode, which has a highly developed form, remains vertical, its lower end being separated from the zinc only by an insulating cross bar, a few millimeters thick.

As soon as the circuit is closed polarization begins, *i.e.*, hydrogen appears on those parts of the charcoal nearest the zinc, and insulates from the liquid the corresponding portion of the charcoal, so that the current continues to pass by the adjacent surfaces which are polarized in their turn, until the current ceases.

But in the Féry cell, since the charcoal stands vertically above the horizontal position it is the lower part of the charcoal which is covered with hydrogen while the upper part is bathed in a liquid saturated with oxygen, from the air dissolved in the upper layers of the liquid. The result is that there is an electrochemical dissymmetry between the upper portion of the charcoal (immersed in the oxygenated liquid) and its lower part (which is covered with hydrogen).

The whole forms a gas battery arranged in short circuit which constitutes the depolarizing couple. This couple begins to operate at the same time as the principal couple (the zinc and the lower portion of the charcoal). The result is that oxygen is set free from the lower portion of the charcoal and combines with the hydrogen proceeding from the principal couple, while in the upper part of the charcoal hydrogen is liberated and combines with the oxygen in the liquid.

In the accompanying illustration V is a glass vessel; C, carbon cylinder; Z, zinc; F, conducting wire soldered to the zinc; A, ring-shaped lid; D, cover of the carbon; B, binding post attached to carbon; S, wooden cross bar. Thus we see that the *local* couple furnishes automatically the precise amount of oxygen required to depolarize the lower part of the carbon, which with the zinc forms the principal couple. Obviously the more actively the oxygen is dissolved and the fitter the charcoal to utilize the oxygen rapidly, the more rapid the depolarization, hence it is advisable to make use of a special quality of carbon and of a liquid surface as large as possible.

As a result of the operation of the battery zinc chloride and ammonia are formed, the latter of which being lighter rises to the top. Obviously, a moment will occur when the upper portion of the zinc chloride will come in contact with the lower layers of the ammonia, the result being the formation of hydrated zinc oxide with regeneration of the salammoniac. The former at first dissolves in the solution of the latter and is afterward deposited upon the carbon and the walls of the vessel in crystals, whose form vary according to the respective concentrations of the liquid. The crystals deposited in the middle of the cell do not interfere with its functioning but a moment finally arrives when the quantity of zinc oxide deposited is so great that it increases the internal resistance. This is the only practical limitation of the capacity of a cell of any given size. As a matter of fact *since the salammoniac is constantly regenerated* it is not used up and it is possible to employ a very thick piece of zinc, thus obtaining a cell of considerable capacity.

The carbon really acts in this cell like a catalyzer whose mere presence favors the union of the electrolytic hydrogen with the oxygen. M. Féry uses a very pure charcoal mounted and annealed in such a manner as to obtain a definite degree of porosity.

While the cell has a lid to prevent too rapid evaporation the usual fatty body floated upon the liquid is omitted, since this would prevent the absorption of the necessary oxygen. As M. Troller neatly observes, this battery actually *breathes* and to cover it with an oil would asphyxiate it.

Remarkable results have been obtained by the battery, which may be stated in brief as follows:

A cell mounted in a vessel 10 cm. square and 22 cm. high, and containing 1 liter of water and 125 grams of salammoniac with a zinc plate weighing 160 grams yields a total energy either in continuous or interrupted service amounting to 125 ampere hours.

THE ISOPERIMETRIC ELLIPSOGRAPH

By J. A. Van Groos

THE machine illustrated in the accompanying drawings is built somewhat like an ordinary ellipsograph. The points x and y, Fig. 1, are adapted to run in grooves a_2 and a_1 at right angles to each other. These points x and y are joined together by means of a right-and-left screw z,

which when turned will cause the points to travel toward or away from each other. The machine will make all possible ellipses from a circle to a straight line. It is absolutely exact for these extreme positions of x and y, that is, the circumference of the circle is exactly equal to twice the straight line.

But as shown in the enclosed table of semiperimeters, the semiperimeter gets shorter by about 2 inches in 31, or about 6.4 per cent. This is corrected by means of a cam

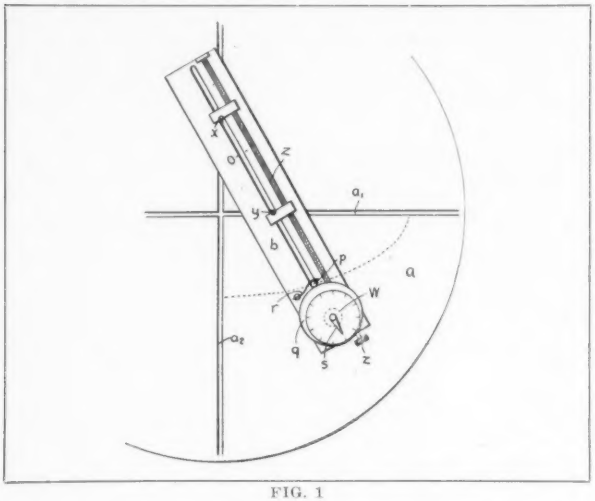


FIG. 1

q, which moves when z is turned. The cam makes a complete revolution while the points x and y move from one extreme position to the other. During the tracing of a certain ellipse, the points x and y and the cam q are stationary with respect to the screw z.

To illustrate the machine diagrammatically, let MN and RT (Fig. 2) be the grooves; x and y the moving points; CD the limits of x and CP of y. The tracing point is at P. The points x and y must move on the screw z in such a way that when y goes through a distance CP, say CP $= 10$, x must go through a distance $5\pi - 10$. For if CP $= 10$, then when x and y are both at C, P will describe a circle with radius 10, and hence with circumference 20π. Also, when x is at D and y at P, P will describe a straight line; hence DP must equal 5π. Therefore

$$CD = 5\pi - 10 = 5.707$$

$$\frac{Cx}{Cy} = \frac{CD}{CP} = \frac{5\pi - 10}{10} = \frac{\pi - 2}{2}$$

$$\text{or} \quad Cx = Cy\left(\frac{\pi - 2}{2}\right)$$

Now assign values to Cy (Col. I Table I); then Cx can be found (Col. II Table I); and $10 + Cx = xP = a =$ semimajor

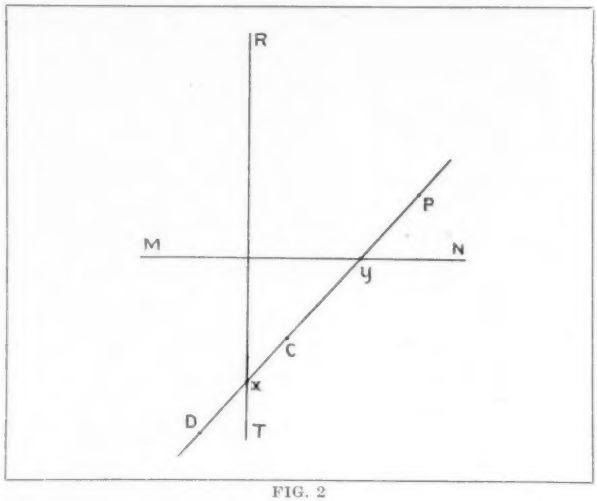


FIG. 2

axis (Col. III Table I), while $10 - Cy = yP = b =$ semiminor axis (Col. IV Table I). Also,

$$e^2 = \frac{a^2 - b^2}{a^2};$$

hence log e can be found (Col. V Table I). Then get arcsin e from table of trigonometric functions (Col. VI Table I); get E from table of elliptic integrals (Col. VII Table I); get $2aE$ or semiperimeter (Col. VIII Table I); and Col. IX Table I shows corrections to be made by cam.

The size of the cam q is readily found. For example, see Table II. I find, by trying different value of b, when $Cy = 5$, that b should have a value between 5.66 and 5.67 instead of 5 as given by Table I.

TABLE I

Cy	Cx	xP=a	yP=b	log e	sin⁻¹ e	E	2aE	Corrections
0.00	0.0000	10.0000	10.00	$-\infty$	0° 0′ 0″	1.5708	31.4159	0.0000
1.00	0.5708	10.5708	9.00	9.719757–10	31° 38′ 8″	1.4564	30.7906	0.6253
2.00	1.1416	11.1416	8.00	9.842617–10	44° 6′ 28″	1.3585	30.2717	1.1442
3.00	1.7124	11.7124	7.00	9.904045–10	53° 18′ 0″	1.2744	29.8526	1.5633
4.00	2.2832	12.2832	6.00	9.940856–10	60° 46′ 18″	1.2037	29.5706	1.8453
4.50	2.5686	12.5686	5.50	9.953842–10	64° 2′ 57″	1.1727	29.4784	1.9375
5.00	2.8540	12.8540	5.00	9.964433–10	67° 7′ 37″	1.1442	29.4265	1.9894
5.25	2.9967	12.9967	4.75	9.968865–10	68° 33′ 50″	1.1312	29.4037	2.0122
6.00	3.1394	13.1394	4.50	9.972908–10	69° 58′ 18″	1.1187	29.3981	2.0178
5.50	3.2821	13.2821	4.25	9.976544–10	71° 20′ 17″	1.1068	29.4013	2.0146
5.75	3.4248	13.4248	4.00	9.979812–10	72° 39′ 54″	1.0955	29.4137	2.0022
7.00	3.9956	13.9956	3.00	9.989790–10	77° 37′ 30″	1.0559	29.5560	1.8599
8.00	4.5664	14.5664	2.00	9.995867–10	82° 6′ 30″	1.0272	29.9252	1.4907
9.00	5.1372	15.1372	1.00	9.999049–10	86° 12′ 33″	1.0079	30.5136	0.9023
10.00	5.7080	15.7080	0.00	10.000000–10	90° 0′ 0″	1.0000	31.4159	0.0000

TABLE II

Cy	Cx	xP=a	yP=b	log e	sin⁻¹ e	E	2aE	Corrections
5.00	2.8540	13.3540	5.50	9.959636–10	65° 40′ 40″	1.1576	30.9172	+0.4987
5.00	2.8540	13.5140	5.66	9.958118–10	65° 14′ 20″	1.1616	31.3957	+0.0202
5.00	2.8540	13.5240	5.67	9.958023–10	65° 12′ 44″	1.16184	31.4254	−0.0095
5.00	2.8540	13.5340	5.68	9.957978–10	65° 12′ 0″	1.16194	31.4530	−0.0371
5.00	2.8540	13.5200	5.6666	9.958067–10	65° 13′ 30″	1.1617075	31.41257	+0.00335

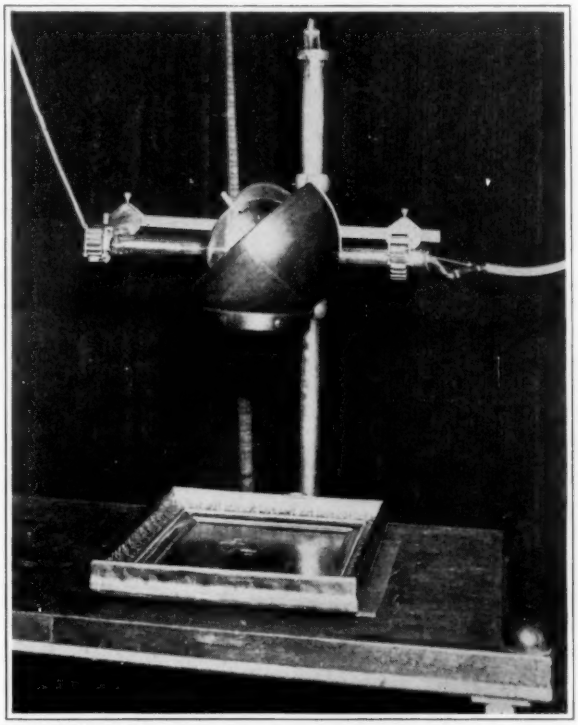
X-Ray Tests of Old Paintings

Remarkable Differences Between Ancient and Modern Pictures Revealed by X-Rays

By May Tevis

IN one of his note books Nathaniel Hawthorne relates the story of a man who, being in possession of a beautiful painting perceived upon close scrutiny that it had been painted not upon a fresh surface but upon the top of an older painting. Inspired by curiosity and imagining, perhaps, that the older picture might represent a greater value, he removed the upper layer of pigment to find, alas, that he had sacrificed a charming painting only to uncover a worthless daub. Had the unfortunate owner lived in this our 20th century, he need have taken no such risk, since researches recently made in several European countries show that the connoisseur now has an admirable implement in the shape of the X-ray with which to supplement his critical judgment concerning the antiquity of pictures and one revealing whether they were painted upon a virgin surface or upon one bearing a previous work of art.

The first researches along this line are said to have been made in Germany in 1914, and they were described by Faber in the *Zeitschrift f. Museumkunde*. Similar studies were pursued in Holland by Dr. Heilbron of Amsterdam, and some very interesting results were obtained by him. More recently a French expert, Dr. Chéron, has obtained results still more definite and more remarkable, some of which are indicated in the illustrations which are reproduced with this article.



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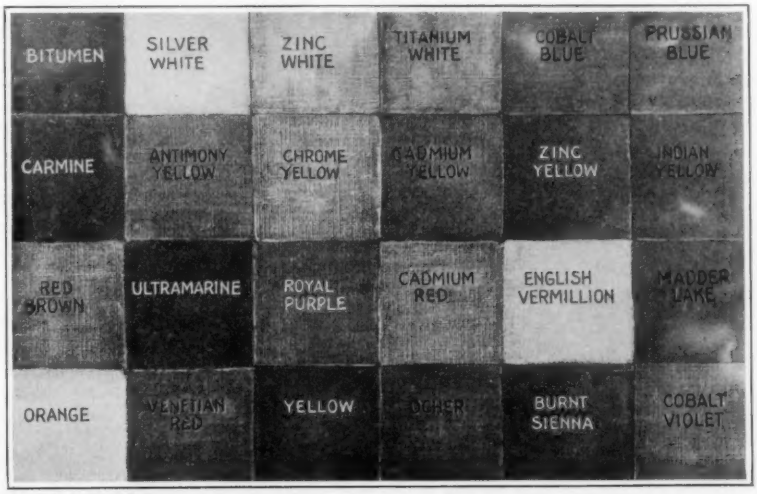
DR. CHÉRON'S APPARATUS FOR MAKING X-RAY PICTURES OF PAINTINGS

The degree of transparency to X-rays exhibited by any body depends upon the number and atomic weight of the atoms composing the said body. It is obvious that in every picture there are three substances to be considered from this point of view. In the first place there is the surface which is painted upon; this surface is usually either canvas or wood, especially in the case of earlier paintings; however many other materials have been experimented with by different artists at different times, including plaster, ivory, paper, leather, silk, china and pottery and even cobwebs. Secondly, there is the priming or sizing which is applied to the surface to prepare it for receiving the colors; thirdly, of course, there are the pigments employed by the artist.

Both wood and canvas, the principal surfaces to which oil paints are applied, are highly transparent to X-rays, but the former is more so than the latter, as might be expected. Different kinds of canvas vary likewise and one of our pictures represents a number of samples of different mesh.

The second element of the picture, the priming or sizing, is usually composed in the case of ancient pictures of carbonate of lime mixed with glue, and this composition has been found to be comparatively transparent to X-rays. Modern artists, however depend almost entirely upon the material known as ceruse (white lead), which is much more opaque in character and which, moreover, penetrates the interstices of the canvas upon which it is spread. Because of this fact the X-rays at once reveal a marked difference in this respect between canvases prepared with a modern priming and those employed by the artists of various centuries.

An even greater difference exists in most cases between the pigments to be found in many of the works of the old masters and those of which modern painters make use. While the ancients employed mineral colors almost exclusively those at the disposal of our modern artists include a number of colors derived from vegetable sources and others from the aniline group which, of course, were entirely unknown previous to the middle of the 19th century. The metallic paints used by the old masters are much more perceptible under the X-rays than



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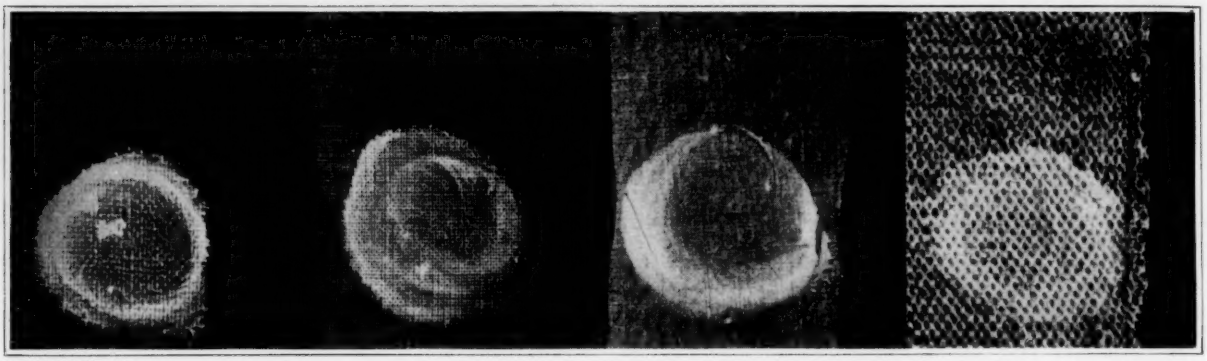
OPACITY OF VARIOUS PIGMENTS TO THE X-RAYS



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RADIOGRAPH OF STRIPS OF CANVAS SHOWING THEIR TRANSPARENCY TO X-RAYS

modern paints made of vegetable and aniline dyes.

As we have said, pigments vary greatly in their density and, consequently, in their degree of transparency to the X-rays. Some of them, like white, are now, and have always been, indeed, composed almost exclusively of heavy salts such as those of lead or zinc; hence they present a serious obstacle to the passage of the rays. Most of the blacks, on the other hand, including bitumen, which is much employed by painters for certain purposes, are extremely light and, therefore, readily allow the rays to pass. Between these two extremes we find a long series of the most various atomic weights among colors, from the very light carmine to the heavy chrome yellow, ranging through cobalt blue, ultra-marine, burnt sienna, Verona green, English vermillion and orange.

But a number of colors, as we remarked above, which were formerly composed of mineral salts, such as most of the reds for example, are frequently prepared nowadays from materials of plant origin, which are much more transparent, as is madder for example. The same thing is true of colors having an aniline base.

ESSENTIAL FACTORS IN OBTAINING A GOOD RADIOGRAPH

It is obvious that in order to obtain a satisfactory radiograph with comparatively clear outlines and a sufficient degree of contrast between the dark and the light areas two factors are all important. In the first place both the surface to be painted and the coating or sizing spread upon it before the pigments are applied must be transparent to the X-rays. Secondly the colors must be comparatively opaque, at least in the case of those whose contrasts form the images portrayed.

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A FLEMISH SCENE ATTRIBUTED TO VAN OSTADE

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RADIOGRAPH OF THE ABOVE, SHOWING THAT IT WAS PAINTED IN MODERN COLORS OVER AN OLD PAINTING OF A BARNYARD SCENE

Note the two peacocks in the center foreground and the ducks at the right. The white spot is a lump of wax on the back of the picture. Above and below it may be seen very faintly two of the heads in the later picture.

Luckily it is precisely these conditions which we find in the pictures of the old masters in general. Modern pictures on the other hand very commonly reverse these conditions since the sizing employed is comparatively opaque while the pigments are often considerably more transparent. Under these conditions the images produced will be more or less faint and indistinct — sometimes indeed they are so shadowy as to be almost invisible. The writer remembers seeing one such radiograph in which the canvas looked almost bare, though the picture it was made from represented a brilliant flower arrangement with effective contrasts of color and of light and shade.

It is for these reasons that radiographs throw a most valuable light upon the probable age of a picture, so that after devoting some study to their observation in the case of authentic paintings of a given era, or by the hand of a known

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PHOTOGRAPH OF THE MADONNA OF THE STAR, A XVII CENTURY PAINTING, AND RADIOGRAPH SHOWING THE MARRED ORIGINAL AS IT MUST HAVE APPEARED BEFORE RESTORATION BY A MODERN ARTIST

painter, the connoisseur can readily detect modern "fakes," or rectify an honestly made mistake with regard to a picture wrongly attributed to a given school or master.

DETECTING EVIDENCE OF EARLIER RETOUCHING

But the radiograph does even more to assist in the correct appraisal of an old picture's value, since it reveals the ravages and defacements which it may have undergone from time to time during the centuries since its author laid down his brush, no matter how skilfully these have been concealed by the process known as retouching. The very fact that retouching is done at a later date than that of the picture's origin and usually by a different hand makes it highly probable that all the materials employed in the repair work, whether the pigments, the sizing, or the canvas itself, are of different manufacture and different atomic weight. When this is the case the repair work will show up in the radiograph in the form of spots of definite outline. Sometimes areas of a picture are discovered in this manner to be by a later hand though the presence of retouching had been absolutely unexpected until the magic rays revealed the evidence of early injury and skilful repair. Possibly some of our public museums and private owners will be none too anxious to submit their more doubtful treasures to the too penetrating vision of this modern mechanical detective of fraud, the X-ray tube. How painful to discover that a cherished Flemish or Italian masterpiece reputed of the 15th or 16th century in date was really the product of 20th century skill and fraud in some obscure studio of Paris, Antwerp or Berlin. On the other hand there is at least a possibility that a banal piece representing early Victorian taste, let us say, has been painted on top of a misprized masterpiece of earlier date.

An instance of fraud is illustrated on the opposite page. The picture in question shows a scene of festivity—a party of merry-makers playing upon musical instruments and dancing. The work is Flemish and was formerly attributed to Van Ostade. The radiograph made of this picture is very surprising and curious. The gay party of dancers have all vanished into thin air, except for the ghostly heads of two of them which can be dimly discerned in the middle of the image. In place of them we see upon the proof tolerably clear outlines of the figures in an entirely different painting—one of a barnyard scene which had evidently been previously painted upon the same panel of wood. The figures of two peacocks, two ducks, and a couple of chickens can be quite plainly seen. This barnyard scene is apparently quite old since there is no opaque sizing to disguise the outlines of the figures. The supposed or faked Van Ostade is probably modern since all its colors, except for the blues, are almost uniformly transparent to the X-rays.

Another interesting picture examined in this manner by Dr. Chéron not long ago is the picture of the Royal Infant at Prayer hanging in the Louvre Museum and ascribed to the French School of the 15th century. The curators of the collection had reason to believe from certain documents in their possession that the original background of the picture had suffered great deterioration and that this had been hidden or masked about a century ago by the application of the uniform black background seen in it at present. The radiograph taken by Dr. Chéron brilliantly confirmed this hypothesis. The black background proved perfectly transparent to the X-rays, revealing beneath it the badly damaged original background of a lighter tone.

The Madonna of the Star is also an admirable illustration of the effectiveness of the X-rays in revealing the outlines in an authentic picture of early date, the figures being quite clearly visible. Across the middle of the radiograph there is a band of white showing that the original must have been damaged at this point and restored by an artist using modern pigments. The radiograph also reveals deterioration at bottom of the picture which was restored in comparatively recent times.

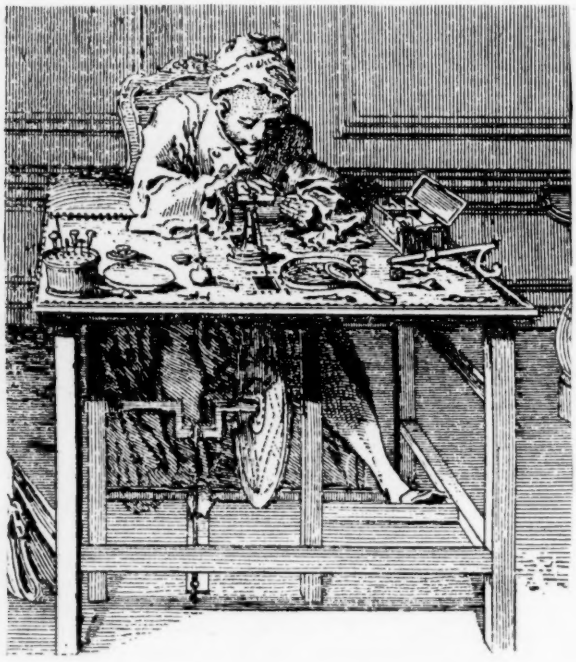
Ancient Gem Engraving

The Engraved Gems of the Metropolitan Museum of Art

Reviewed by Albert A. Hopkins

THROUGH the courtesy of the assistant curator of the Department of Classical Art of the Metropolitan Museum of Art, Dr. Gisela M. A. Richter, we have received a "Catalogue of Engraved Gems of the Classical Style" beautifully illustrated with 88 plates comprising 463 figures. While the literature on engraved gems is extensive still this catalogue furnishes a worthy treatise in English on the subject, and is an excellent cicerone to the beautiful collection on Fifth Avenue.

The present catalogue deals only with gems of the classical style both intaglios and cameos, omitting the Oriental, Sassanian and Gnostic gems which have a different appeal. The eighteenth and nineteenth century gems of pseudo-classical



EIGHTEENTH CENTURY ENGRAVER AT WORK
From Mariette's Pierres Gravés

style have been placed with the classical material, since their chief importance lies in their approximation to the classical style. The catalogue is divided chronologically into the chief periods of ancient art, and within these chronological divisions it arranges the gems according to subjects. Each section is preceded by a short historical note showing the influence of contemporary events on the art of gem engraving.

A collection of ancient gems satisfies our æsthetic sense in many ways. The inherent beauty of the material, with its rich and varied colors, its luster and brilliance, gives us pleasure at first sight. The hard and durable quality of the stones has made for unusually good preservation, so that we can appreciate in many cases the artist's work in its original state—a rare opportunity in classical art. Moreover, the smallness and preciousness of the gems invited exquisite workmanship, and in certain periods when the art was at a high level the achievements in this field were very notable. The best ancient gem engravers combined extreme minuteness and accuracy of detail with a largeness and simplicity of style that are indeed remarkable. A gem engraving of this class possesses the nobility and dignity of a marble or bronze sculptural work, though it is often confined to the space of less than half an inch square.

This quality of combining minute size and exquisite finish with grandeur of effect lifts these gems out of the class of decorative objects and puts them on a par with the products of the higher arts. And yet, though the best ancient engravers could give this sculptural quality to their work, they kept strictly to the technique of their own trade. They showed great skill in the treatment of the intaglio relief, observing—at least in the best periods—a certain uniformity of surface and avoiding excessive projections. The compositions are cleverly designed for the field they occupy, falling easily within the prescribed limits without any feeling of restraint or confinement. And this applies not only to single figures in all manner of poses but to the not infrequent groups; for even where several figures are introduced or various objects related to the scene are added, there is rarely a sense of crowding—so perfectly is the design suited to the space.

Not only do classical gems follow closely the prevalent styles of their periods, but the choice of subjects represented on them is equally inclusive. These subjects comprise, in fact, the mythology and the daily life of the Greeks, the two great themes of classical art. Thus, in a representative collection of gems we can pass in review almost every Greek god, goddess, and hero, as well as many subjects of everyday life, especially portraits and animals. And, since this is the case for so extended a period, we have here an exceptionally comprehensive picture of the development of classical types. We shall find that, varied as the subjects on the gems are, they teach us again the lesson we learn in our contact with all Greek and Roman art—that the classical mind preferred to adopt certain types and repeat these, of course with infinite variations, rather than try to produce continually fresh models and themes. This adherence to certain standardized types makes the ancient work, even when carelessly executed, usually fine in composition and space filling, and, viewed as a whole, it impresses us with that sense of vitality controlled by order and purpose which is so prominent a characteristic of classical art.

In order to understand fully the representations on gems, we must bear in mind another important characteristic of classical art—its symbolism. By this we do not mean an abstruse symbolism to express abstract ideas, by which some moderns still delight to interpret Greek art—for that is essentially un-Hellenic; but a perfectly obvious symbolism, by which a flower stands for a flowery meadow, waves for the sea, a chair for an indoor scene, a column for a house; in other words, by which a small concrete part stands for the concrete whole. We are familiar with such a shorthand method of expression even in Greek vase paintings; its advantage in the restricted space of a gem is apparent.

GEMS AS SEALS

Besides their artistic and historical value, classical gems make a strong appeal to us through their intimate relation to the personal lives of the Greeks and Romans. Their primary object was to serve as seals, and seals in the ancient world played a very important rôle. They took the place of Yale keys and combination locks; for the Greek and Roman householder would guard against the infidelity of his slaves by placing his seal on the doors of chambers and closets in which he kept his jewelry, his secret papers, his supplies, and

other precious belongings. Many ancient sealings of all periods have been found, chiefly of clay, and the ancient writers often refer to this practice. In the Thesmophoriazusae of Aristophanes, for instance, the women complain that the stores of meal, oil, and wine are guarded too well by

ENGRAVED GEMS IN THE METROPOLITAN MUSEUM OF ART

1. Rock Crystal Ringstone of Serapis—Hellenistic Period. 2. Carnelian Ringstone Head of Asklepios Graeco-Roman Period. 3. Girl Dancing Gold Finger Ring. Developed Greek Style. 4. Carnelian Ringstone of a Sculptor. Italic, First Century B. C. 5. Banded Agate Showing a Crane. Developed Greek Style. 6. Herakles—Archaic Greek Period

their husbands' seals; and Isokrates is shocked by the action of Pythodoros, who opened the voting urns, "sealed by the Prytanes and countersealed by each of the Choregoi." Again, Horace describes an amiable neighbor who is kind to his slaves and "does not go mad when the seal of his wine jar is broken."

Furthermore, the seal in the ancient world corresponded to a written signature today. At a time when the large majority of people were unable to write and had to depend on the services of the professional scribe, the impression of a personal seal was the only reliable identification mark. And in the days before the handling of mail by a government postal service, such identification marks were doubly necessary, for all correspondence had to be entrusted to private carriers who might or might not be trustworthy.

The danger of having one's seal fall into the wrong hands was naturally great, and could entail serious consequences. The story of Hannibal's appropriating the seal of the Roman general, Marcellus, and almost capturing a town in consequence is well known (cf. Livy, XXVII, 28). To forestall such deceptions it was best to have one's seal in safe-keeping before death, and either to destroy it, or to give it to a trusted friend, as Alexander did to Perdiccas (Quintus Curtius, X, v, 12, and Aemilius Probus, In Eumenen, II, 1), and Augustus to Agrippa (Dio Cassius, LIII, 30). If one had no such trusted friend, one's position was difficult. Suetonius tells that Tiberius on his deathbed pulled off his ring to give it to a bystander and after some hesitation replaced it on his finger (Suetonius, Tiberius LXXIII, 2).

CHOICE OF DESIGNS ON GEMS

In the choice of designs for seals we have seen that the ancients drew from the prevalent artistic stock. It would have been an alien thought to a Greek or Roman to use for his device merely his monogram, as we might nowadays. His name or initials might appear occasionally on the gem in a secondary place; but the principal design would be pictorial. And yet, though the selection was made from the general store, there must often have been a special appropriateness in the chosen device, as in the family crests or the individual book-plates of today. The choice was apparently oftenest a favorite deity, or mythological hero, or animal, or symbol: sometimes it commemorated a glorious event in the family or a personal deed of valor, or it was the portrait of an ancestor, or friend, or leader. Often, again, there would be no special relevancy—but the design would be a beautiful composition that appealed to individual taste. It is, indeed, just this element of individuality which differentiates the gems from other classical monuments and gives them much of their charm: they are not only the precious possessions of individuals employed by them for their own particular uses, but they were in most cases probably specially made for these individuals and so express their personal choice.

An engraved gem used for an official purpose is very near in character to a coin; for coins are the public counterpart, so to speak, of gems; they bear the seal of the state, while gems bear the seal of the individual. Naturally the connection between these two types of monuments must have been close, since they presented similar problems to their makers. Often we find the same motives on the coins and gems of one period; but the gems which represent individual taste show a much greater variety of subject than the coins which bear the emblems of cities. Doubtless the Greek mints were a constant source of inspiration to the gem engravers, and it is probable that sometimes the same man was master of both arts.

Besides serving the practical purpose of sealing, engraved gems were often used by the ancients merely as ornaments, the combination of a precious material and an artistic representation making such a use singularly appropriate. The varied colors and the glitter of the stones were, of course, to many attraction enough, so that unengraved stones were employed much more generally for this purpose than the engraved ones. But we can imagine that, to the discriminating at least, the

FRAGMENT OF A LARGE ONYX CAMEO OF THE GRAECO-ROMAN PERIOD

pleasure in a beautiful engraving far outweighed the more primitive delight derived from sparkling stones.

GEMS AS AMULETS

In addition to serving as seals and as ornaments, gems in ancient times played an important rôle as objects supposed to have curative and protective power. Even nowadays the belief in the magical properties of certain stones is still preva-

lent with many people; so that we can easily understand how in a less scientific age such ideas were both widespread and deep-rooted. We have abundant evidence for this both for Greek and Roman times. Aristophanes speaks of the "medicinal ring" which druggists evidently sold cheap to their clients in the place of drugs. Such rings, we are told, could avert the evil eye and guard against snakes. The learned Pliny in the thirty-sixth and thirty-seventh books of his Natural History quite seriously gives us a long account of the magical properties of stones.

The diamond, he says, cures insanity and vain fears and prevents poisons from harming; the amethyst prevents drunkenness; if engraved with the name of the sun or moon and hung around the neck with hairs of a cynocephalus or with swallow's feathers, it is an antidote for poisons, gives right of access to kings, and averts hail and locusts. An emerald engraved with an eagle does the same; a certain kind of agate is beneficial against bites of spider and scorpion. Hematite is good for the eyes and liver, gains requests addressed to kings and is useful in lawsuits; mixed with juice of pomegranate it cures those who vomit blood. Sideritis increases anger between parties to a lawsuit and so on, through a long list. There certainly were compensations in an unscientific age when you could believe such entertaining things.

THE TECHNIQUE OF GEM ENGRAVING

Only soft stones and metals can be worked free hand with cutting tools; the harder stones require the wheel technique. This technique was known to the Minoans, who learned it perhaps from the Babylonians, by whom it was practised at least as early as 1,500 B. C. The method of work of the ancients seems to have been very similar to that in use today, to judge by the references we have to this work in classical literature, by an examination of the stones themselves, and by the scanty evidence of actual representations of gem engravers. By this method the stones are worked with variously shaped drills which are made to rotate by the help of the wheel. The cutting is not done by the drills, which are of comparatively soft metal (they are now of iron, not steel, and in Mycenaean times at least must have been of bronze or copper), but by the powder which is rubbed into the stone with the drill. This is nowadays the diamond powder mixed with oil. What it was in ancient times is not certain, as we do not know how early the diamond became known. It was certainly familiar to the Romans, as it is mentioned both by Pliny and by M. Manilius. The type of wheel used in our times is either one worked by the foot or by an electric motor lathe. The former, though more cumbrous, has the advantage of giving the artist more direct control over the speed. On a gravestone of a gem cutter of the Roman Empire found at Philadelphia in Asia Minor, a tool is represented which looks like the bow used by modern jewelers. This, by being drawn quickly back and forth, could impart a rotating movement similar to that of the wheel. But since we know that the wheel was well known to the ancients, in the making of pottery, for instance, it is certainly probable that they made use of it in gem engraving also.

Nowadays the stone to be engraved is fastened to a handle and held to the head of the rotating drill and moved as the work requires. It has been suggested that the ancients reversed the process and held the stone stationary while the rotating tools were guided by the hand, as in modern dentistry. There is no means of settling this point, which in itself is unimportant.

The shapes of the tools must have been essentially the same as those in use today, ending in balls, disks, cylinders, etc., in all sizes ranging from about a quarter of an inch to a pin point.

It is a debatable question how much the diamond point was used in ancient times for fine detail lines. It was apparently used hardly at all in the earlier Greek period, but on Hellenistic and Roman gems we occasionally find fine lines with sharp edges which could only have been made by such means. The lines produced by the help of the wheel would always have round edges. The passage in Pliny, which speaks of small diamond particles "ferro includuntur" has been interpreted as referring to the use of the diamond point; but Pliny's account is so general that it may refer simply to engraving with diamond powder. The modern gem engravers never use the diamond point.

After the cutting of the gem was complete the surface was often polished. In pre-Hellenic gems the engraving was either left dull or the polish was confined to the larger surfaces. Etruscan scarabs, on the other hand, show a high polish, even when the work itself is careless. Beginning with the Hellenistic period and throughout the Graeco-Roman times the more carefully worked gems show a detailed and often high polish. Nowadays for outside polish engravers use very fine diamond powder and oil applied on a very hard wooden tool (generally boxwood). For the inside polish tripoli powder mixed with water is used on a copper tool or on a stiff brush made to rotate on the wheel. The ancients appear to have used Naxian stone (maximum) for this purpose, to judge from a statement by Pliny.

MATERIALS USED FOR ANCIENT GEMS

The favorite materials employed by the Greeks and Romans for their gems were at all times the colored quartzes. These had the advantage of being easily worked on the wheel and still being hard enough for general use; moreover, they came in beautiful colors and could be finely polished. Especially popular were the chalcedonies or non-crystallizing quartzes. Besides the quartzes, the ancients also used harder, more precious stones, as well as a few inferior varieties and glass pastes.

These were principally Carnelian, Sard, Chalcedony, Plasma, Jasper, Agate, Rock Crystal, Amethyst, Garnet, Emerald, Aquamarine, Topaz, Peridot, Moonstone, Sapphire, and Turquoise, while Lapis Lazuli and Malachite were sparingly used. The inferior varieties were Hematite, Steatite, Serpentine and Porphyry. Glass pastes were used as cheap substitutes.

COTTON DYEING—PAST AND PRESENT

PROFESSOR L. A. OLNEY, in the *American Dyestuffs Reporter*, gives an historical outline of the science of dyeing, the development of union colors, classification of coal-tar dyes, sulphur colors, Turkey red and Para red, vat dyeing and some reference to dyeing machinery, all of which are contained in a short article which will be of interest to any seeking to be better informed upon this important subject. In view of the increase in the usage of dyeing terms, the following quotation is made from the article in question:

"The coal-tar dyes may be classified in several different ways, but for the use of the practical dyer there is but one satisfactory method, namely, that which divides them according to their action upon the different fibers; in other words, according to their methods of application. This classification recognizes ten groups as indicated in the following table. The fibers to which these dyes are applicable are also indicated in each case, and their most important uses in *italic* type. A blank line indicates that dyes are either not used at all or their application is too limited to be of consequence.

Class of Dye.	Fibers upon Which They are Applicable		
1. Basic dyes	*Cotton*	Wool	Silk
2. Eosins and related dyes	Cotton	Wool	*Silk*
3. Acid dyes	.....	*Wool*	Silk
4. Direct cotton colors	*Cotton*	Wool	Silk
5. Sulphur dyes	*Cotton*	.....	....
6. Mordant dyes	Cotton	*Wool*	Silk
7. Mordant acid dyes (after chrome colors)	.....	*Wool*	Silk
8. Insoluble azo dyes	*Cotton*	.....	....
9. Reduction vat dyes	*Cotton*	Wool	Silk
10. Aniline black	*Cotton*	.....	....

Fireproofing Fabrics*

Treatment of Sack Materials, Tent Cloths and Balloon Fabrics

By W. Hacker

THE methods used in fireproofing various fabrics consist in impregnating the fibers with solutions of different chemicals or in covering them with coatings which either evaporate or melt in the heat. Complete non-inflammability cannot of course be obtained as long as the fibers themselves are of an organic origin. The chemicals, which are used most generally for this purpose, are the easily fusible borates, phosphates, stannates (tin salts), tungstates, molybdates and titanates. Frequently, ammonium salts are also added.

Of all the various substances which can be used to fireproof fabrics, the most important and most efficient are ammonium sulphate and ammonium phosphate. While borax, boric acid, water-glass, aluminum salts, stannates, tungstates, or the salts used for wood impregnation, iron, copper or zinc sulphate solutions, mixed with calcium or barium chloride, are all very useful and valuable, none of them can surpass the ammonium salts in the effectiveness of its action.

The technology of the fireproofing of textiles and other combustibles has been discussed in great detail by P. Lochtin in *Dingler's Journal*, Vol. 290, p. 230. A great many salts are described and classified according to their action in this respect, that is, whether they promote, hinder or are indifferent to the propagation of the combustion phenomenon in combustible materials. It was found that the following salts render cellulose non-inflammable, viz.: ammonium phosphate, ammonium sulphate, sal ammoniac (NH_4Cl), the chlorides of calcium, magnesium and zinc, tin sulphate, tin salts in general, alum, borax, boric acid and aluminum hydrate.

THE SILICATES AS FIREPROOFING AGENTS

Lead orthosilicate ($Pb_2S_1O_4$) was used for the first time by Abel in fireproofing textile fabrics. A mixture of glycerin and asbestos or graphite is used to coat fabrics so as to render them fire-resistant. The fiber is soaked in a linseed oil varnish either before or after being treated with the glycerin mixture and is finally painted with an oil color. (German patent 102,314.) Another method is to apply an undercoat of a composition, consisting of kieselguhr, chalk and linseed oil and a top coat of a molten mixture of water-glass, calcium chloride and common salt (German patent No. 108,723).

A Swedish patent (No. 25312, 1907) has been issued on a method of fireproofing fabrics by impregnating them with a concentrated solution of alum, which is mixed with potash, common salt and a suspended solution of turpentine and asbestos in muriatic acid. Before using, the mixture is diluted with twice its weight of water and mixed with a little flour and water glass. A mixture of sodium silicate and soap together with small amounts of glycerin, sodium tungstate and oleic acid, saponified by means of calcium carbonate, is also used according to British patent No. 717, 1909.

BORAX AND AMMONIUM SALTS

Very good results have been obtained with the use of these salts in conjunction with other substances. As an example, 80 kg. of aluminum sulphate, 25 kg. of sal ammoniac, 30 kg. of boric acid, 17.5 kg. of borax and 25 kg. of starch are dissolved in 1,000 liters of water. Separate solutions of 50 kg. of alum or ammonium phosphate, or 150 kg. of borax and 110 kg. of magnesium sulphate are also advocated, each solution being used in succession. Another mixture consists of 20 kg. of borax, 60 kg. of alum and 10 kg. of sodium tungstate. It is best to impregnate the cloth with the phosphate solution first, then to treat it with a dilute solution of ammonia, containing magnesium chloride and finally to wash it with very dilute ammonia. English patent No. 15382, 1887, advocates the use of calcium chloride and ammonium phosphate. Still another method is to impregnate the fabric with an aqueous solution of calcium ammonium salts, then to apply a solution of soda and to paint it with a mixture, containing alumina, talc, kaolin and colored varnish, ground in alcohol.

A very effective fireproofing composition, patented in Norway (No. 17803, 1906) consists of 5 to 15 parts of phosphate and 85 to 95 parts of tungstate (50 to 75 parts of phosphate-tungstate can also be used) in one liter of water. The impregnated material is washed thoroughly and the process is repeated. An aqueous solution of equal parts of calcium acetate and calcium chloride has also been used for this purpose.

In the *Seifensieder Zeitung*, 1911, page 955, there is described a method of fireproofing fabrics by the use of a mixture, consisting of one kilogram each of sodium hyposulphate, maize starch, common salt, talc and 500 grams of borax. The materials are dipped for 2 to 3 minutes into the lukewarm pasty mass and then dried. French patent No. 456589 describes a method for fireproofing fabrics of all sorts by immersing them first in a 65 per cent solution of alum, then drying and submerging them in a 50 per cent ammonia sulphate solution, wherein they are allowed to remain over night. They are then dried slowly. A novel process for rendering textiles resistant to heat is revealed in U. S. Patent No. 1048912, wherein a caoutchouc solution containing ground mica and pulverized asbestos, is used.

FIREPROOFING COTTON FABRICS. "NON-FLAM"

It is often necessary to wash fabrics and it is desirable that they do not lose their fire-resistant properties after they are washed. W. H. Perklin has invented a process of treating flannel so that it is possible to wash the goods without any danger of their becoming inflammable again. This is done by steeping the pieces of flannel completely in a 45° Tw. solution of sodium zincate. The excess solution is squeezed out and the material is dried in copper drums. When the cloth is thoroughly dry, it is impregnated with a 15° Tw. solution of ammonium sulphate, pressed again and dried once more. The cloth is then washed to remove the sodium sulphate, whereat it is dried for the third time and is then ready for use. It has been established by means of numerous tests that the colors in the flannel are not injured in any way; that the insoluble tin salts precipitated on the fiber do not attack the skin; that the tensile strength of the flannel is increased about 20 per cent and that the non-inflammability of the treated fabric remains intact after 25 washings by hand and 35 washings with a washing machine. This cloth is known as "Non-Flam" in the trade.

USE OF STANNATES

According to German patent No. 150465, a 22° Bé. solution of sodium stannate is used to impregnate fibers to render them fireproof. The material is dried after this treatment and then passed through a 16° Bé. solution of zinc acetate. It is well to wash the size out of the cloth before putting it through the fireproofing process. Furthermore, the material is generally soaked in olein, soap or glycerin after being washed, which renders the action of the metallic salts more effective.

In a similar manner, wood, paper or textile fabrics can be made fire-resistant (German Patent No. 151641) by passing them through a bath of sodium stannate after a preliminary washing (sp. gr., 1.04 to 1.08) and then through another bath,

*Translated for the *Scientific American Monthly* from *Kunstoffe*, 61-4, 1920.

containing 33 per cent titanium sodium sulphate and 7.5 per cent of ammonium sulphate. The last step is to draw the cloth through a solution of water glass (sp. gr. 1.1). Then it is washed and sized in the usual way. It is not necessary to use the stannate solution as the cloth is rendered sufficiently fire-resistant by treatment with the titanium salt alone.

CASEIN COATINGS—ELECTRICAL WIRINGS

When fabrics, wood and other similar materials are coated with casein containing compositions, they are made fireproof as well as waterproof. German Patent No. 220860 describes such a pasty mixture, containing 10 parts of zinc oxide, 10 parts of water and the necessary coloring matter, combined with a solution of 10 parts of casein, 10 parts of ammonia and 10 parts of ammonium bromide in 30 parts of water. This composition carbonizes rather readily, when an attempt is made to ignite it, but it does not burn. It is particularly well suited for impregnating the fabrics used in covering electrical conductors.

TREATMENT OF JUTE

Jute can be sized and made waterproof at one and the same time by the following process (see *Technisches Rundschau*, 1913, 313). The first step is to steep it in a 3° Bé. solution of acetate of aluminum and then to dry it at 50 to 60° C. The treatment is repeated twice and then the jute is sized either in a solution containing 90 grams of protamol, 5 grams of glycerin, 15 grams of vaseline and 100 ccm. of a 3° Bé. solution of aluminum acetate in 790 ccm. of water, or with a mixture of 90 grams of protamol, 30 grams of magnesium sulphate, 5 grams of glycerin and 15 grams of vaseline in 860 grams of water.

Jute and other coarse meshed fabrics can be waterproofed by impregnation with an emulsion of 10 parts of asphalt and 10 parts of cellulose, 5 parts of glue, 1 part of chrome alum, 8 parts of tar oil, 16 parts of benzol and 50 parts of water. For waterproofing linen, used to make sails, H. Jennings recommends the use of zinc soap.

COTTON SAIL CLOTH

The first step in the process of waterproofing cotton sail cloth is to remove the sizing by treatment with wort (malt extract) or caustic potash solution. The cloth is then hung up to dry in a drying loft and further impregnated with a clear 5° Bé. solution of alum at 30° C., made by dissolving 30 kg. of alum in 180 liters of boiling water, which contains 12½ kg. of calcium pyrolignite. After 2 to 3 immersions, the cloth is dried at 40 to 45° C. and, after the vapors of acetic acid have been removed, it is fixed by six successive immersions in a solution of 500 grams of 66 per cent water glass in 150 liters of water, maintained at the boiling point.

WATERPROOFING TENT AND AWNING CLOTH

The waterproofing process consists in painting the cloth with a solution of 2 kg. of alum, 1 kg. of isinglass and 0.5 kg. of white soap in 50 liters of water and then applying a coating, consisting of a water solution of 2 kg. of lead acetate in 50 liters of water. In this way a completely insoluble lead soap is formed in the pores of the cloth, closing them up entirely. (For further details see *Farbe und Lack*, 1912, 24.)

WATERPROOFING SAIL OR TENT LINEN

According to German Patent No. 187027, the waterproofing composition is made as follows. One part of a solution of asphalt in coal tar is cooked for five minutes with 1.5 parts of spirit varnish containing lampblack (black varnish), 2.5 parts of wood tar and 2.5 parts of coal tar. One part of varnish and one part of airproof varnish are added to the cooled mass. The latter is made by dissolving 33 grams of white shellac and 750 grams of sandarac (or realgar, a type of resin, resembling mastic very closely) in 2,000 grams of 95 per cent alcohol and 500 grams of venetian turpentine. This absolutely permanent preparation is painted on both sides of the linen cloth in as thin a coat as possible and is rubbed into the material by means of a hard brush.

Calcium acetate and sulphate of aluminum are used to render linen impervious to water. (For details, see *Oesterr. Woll. u. Lein. Ind.*, 1907, 1379).

An easy method of waterproofing sail cloth (linen) consists in steeping the linen in a 7 per cent gelatine or glue solution, warmed to 40° C. After the cloth is air-dried the gelatinous coating is hardened by means of a 4 per cent solution of alum. The cloth is dried again and washed with pure water. (*Techn. Rundschau*, 1911, 311.)

AGGLUTINANT FOR SAIL LINEN OR WAGON COVERINGS

In the *Seifus Zeitung*, 1911, 314, there is described an adhesive which can be used on sail linen and the coverings for wagons and which consists of 18 parts of gutta-percha, cut up in fine pieces, dissolved in 20 parts of carbon disulphide, 10 parts of benzol and 10 parts of turpentine. After several days, especially if the mixture is heated slightly, complete solution takes place. Then 42 parts of finely powdered asphalt or rosin are dissolved in the solution and the adhesive is ready for use. According to another recipe, 15 parts of finely cut up gutta-percha are dissolved in 45 parts of warm turpentine, benzol or carbon disulphide and 40 parts of a quick drying varnish, mixed with about 10 per cent of manganese drier, are added.

IMPREGNATION OF COARSE FIBERS

A mixture suitable for this purpose consists of 15 liters of boiled linseed oil, 5.5 kg. of pine soot, 0.5 kg. of yellow wax and 0.5 liter of rapid drying oil. After drying, it is covered with a similar mixture; finally the mixture is allowed to dry slowly for four weeks at the room temperature.

Tubes and pipes, made out of sail cloth, can be impregnated with a mixture, consisting of boiled linseed oil varnish, which is obtained by careful heating of raw linseed oil to 150° C. and several hours' cooking at 220 to 230° C. After cooling to 150° C. an addition of 3 to 4 per cent of lead resinate or lead manganese resinate is made.

FIRE HOSE MADE OF SAIL CLOTH

The inside of fire hose made from sail cloth and used under moderately high water pressure is impregnated with a mixture of 11 liters of linseed oil, boiled with 130 grams of ground litharge and 130 grams of umber. (H. Brand in *Farbe und Lack*, 1912, 16). After heating for 24 hours (this must not be done over the open fire), the mixture is ready for use. Two coats are applied as a rule.

A solution of an aluminum soap in turpentine can also be used for this purpose. Instead of painting the hose, the dipping process can be used as well. Another method of treatment consists in an initial immersion in a soap solution and then in a solution of a metallic salt, whereat a water-insoluble metallic soap is precipitated in the pores of the fabric. The first solution, according to *Farbe und Lack*, 1912, 32, contains 4 kg. of alum, 2 kg. of isinglass and 1 kg. of white soap, dissolved in 100 liters of water. The second solution is made by dissolving 2 kg. of lead acetate in 50 liters of water. To dry the coating and to prevent the soap from becoming sticky, a current of cold air is blown through the hose.

TREATMENT OF HEMP FIRE HOSE

Hemp hose, which is to be used at pressures up to 10 atmospheres, must be treated so as to be watertight and also to prevent rotting of the fabric. For this purpose, a tannin solution is used to impregnate the fiber and an inner coating of a solution of gum is applied.

TREATMENT OF BALLOON AND AEROPLANE CLOTH

The fireproofing of balloon and aeroplane cloth is described in *Kunstoffe*, 1913, 438 (see also the work by A. Rost, entitled "A New Use for Cotton"). The manufacture of gas-tight and

water-tight balloon fabrics is covered in British Patent No. 2064-1911. The fabric is made of several layers of goldbeater's skin, cemented together with a gelatine solution and impregnated on both sides with a solution, containing 5 parts of collodion, 5 parts of castor oil and 10 parts of amyl acetate dissolved in 100 parts of an acetone-celluloid solution. The treated fabric is then provided with a layer of silk or wool on one or both sides.

Good results have been obtained by the use of the following mixture, from the standpoint of gaseous impermeability of the fabric. The mixture contains 4 kg. of Para rubber, 30 grams of paraffine (melting at 66° C.), 400 grams of sulphur and 170 grams of magnesium oxide. This preparation is suitable for cloth to be vulcanized at an elevated temperature, while for vulcanization in the cold, the mixture need contain only 4 kg. of Para rubber and 50 parts of paraffine. The tensile strength of the fiber can be increased by impregnation with a mixture of 4 kg. of Para rubber, 40 grams of paraffine, 2.6 kgs. of magnesium carbonate, 360 grams of magnesium oxide and 400 grams of finely powdered sulphur.

According to French Patents Nos. 427818 and 14044, absolute impermeability is obtained by treating balloon fabrics with a varnish, containing a solution of acetyl cellulose and some caoutchouc in tetrachlor-ethane together with an alcoholic solution of a dyestuff.

A newer process of treating balloon fabrics consists in gumming them on the inner side and dusting them with powdered cork. The entire cloth is then cemented fast together by vulcanization. In this way several distinct advantages are gained. In the first place, the layer of cork increases the impermeability of the shell of the balloon, reducing thereby the loss in gas. Then, rapid changes in temperature within the gaseous volume of the balloon are avoided because of the low heat conductivity of the cork covering. Finally, the chemical action of the gases on the material of the balloon is averted. This last fact is of considerable importance, although it has been given scarcely any attention at all.

F. Frank mentions in *Gummiztg*, 1912, 801, that copper and iron have the most deleterious action on balloon materials, as they act as catalysts even in the minutest quantities and cause the formation of acids by the reaction between the sulphur, used in vulcanization, and the oxygen of the air. The best measures of prevention are to paint the fabric with a preventive paint and to impregnate the material with indifferent dyestuffs and metals.

According to German Patent No. 262005 after the balloon cloth is impregnated with a liquid, containing oil, it is covered with "syndeticon" and the sticky fabric is dusted with metallic powder. An impregnating solution, consisting of celluloid dissolved in amyl acetate and admixed with castor oil and wax, is described in German Patent No. 266384.

MANUFACTURE OF WATERPROOF CLOTHING

An article in *Seifens. Ztg.*, 1911, 1177, details the manufacture of waterproof clothing by immensing the cloth in a dilute solution of glue in the first place, which contains about 10 to 20 per cent of linseed oil varnish. Then, after drying, the fabric is impregnated with a decoction of linseed oil varnish with 10 per cent of manganese drier. The elastic properties of the mass can be increased by the addition of 5 per cent of paraffine. Another method consists in impregnation with a mixture of 60 parts of a 15 per cent caoutchouc solution and 40 parts of linseed oil varnish. For dark cloth, a solution containing 15 parts of hard asphalt and 5 parts of paraffine, all mixed with 15 parts of asphalt tar, 10 parts of rosin oil and 30 parts of linseed oil varnish in 25 parts of benzol can be used. Oiled cloth, which has become sticky, must be rubbed with turpentine or benzine until the stickiness has disappeared. After several days, the cloth is varnished.

German Patent No. 65349 describes a method of avoiding stickiness in the oiled coating by coating the cloth with a mixture of linseed oil varnish, petroleum ether, litharge and ammonia.

THE PROGRESS OF CHEMICAL RESEARCH IN TEXTILE FIBERS

EXTRACTS from the annual reports of the Society of Chemical Industry on the subject of chemical research in textile fibers appear in the October issue of the *Color Trade Journal*.

These abstracts show the work divided into cotton, wool, silk, artificial silk, paper yarns, balloon and airplane fabrics, flax, hemp and miscellaneous fibers.

Notwithstanding the large amount of work being done on cotton materials much of the work continues to be applied to yarns and cloth and far too little of it to the ultimate cotton fiber upon which all else depends. One investigator has found that considerable improvement in physical properties such as elasticity, may be obtained by treating the cotton yarns with a solution of caustic soda to dilute for mercerizing. Another finds that mercerizing with, or without, tension tends to increase yarn strength but with a decrease in fiber strength. This latter investigator believes that processes up to the stage of spun yarn have no detrimental effect on the individual fibers. A number of valuable papers have appeared on the subject of purifying cotton and the effect of such an extraction agent as benzol, alcohol, water, ammonia, formic acid, hydrochloride acid, lime and caustic soda, has been examined with special reference to the nitrogen content of the fiber. The total extract amounts to about 4 per cent, and nitrogen from .2 to .26 per cent of the weight of the yarn. Boiling with lime or soap removes less than 50 per cent of the nitrogen present but no other single treatment was so successful as the caustic soda which removes 80 per cent.

On wool, investigations continue into the influence of atmospheric moisture on electrical phenomena and the most suitable conditions for drawing and spinning. In the case of worsted, the degrees of humidity were 77 per cent for drawing, and 50 per cent for spinning. The effect of dry heat on wool has been examined with result that the fall in strength even at 150°C. is only about 3 per cent, but at higher temperatures the sulphur naturally in the wool becomes oxidized to sulphate and in the presence of moisture causes rapid decomposition.

Scouring continues to be a live topic for research including the absorption of soap by the wool in aqueous solutions. It has been found that from 3 to 6 per cent of fatty acid may be absorbed by cross-bred serge, and that the cloth may retain from .4 to nearly 1 per cent even after boiling in water.

The resistance of wool to weather has previously been discussed and it will be recalled that fiber treated with chromium salts is much more resistant to the destroying action of the weather.

Most of the work in silk has to do with boiling off processes, the possibility of using enzymes to destroy the natural silk gum and the question of grading and classifying raw silks. Notwithstanding the increasing popularity of artificial silk, there appears to be less and less literature concerning it excepting in an occasional item on distinguishing natural from artificial silk.

The use of paper yarns for clothing textiles in Germany has lessened with the appearance of cotton as was to be expected. In Japan interest is being shown in the possibility of weaving paper with hemp, silk, and cotton fibers. "Oriental Panama" is of Japanese origin and is produced by coating twisted papers with solutions of nitro cellulose or nitro celluloid.

Balloon and airplane fabrics continue to hold interest and involve the development of tests for such fabrics, methods of determining their probable rate of deterioration in advance, and permeability to various types of gases, methods for rendering them rainproof and ways of using cotton fabric to substitute for linen fabrics on wings.

Under flax, hemp, and miscellaneous fibers may be mentioned researches designed to produce improved strains of flax and investigations into the problem of retting. It appears that the principal agent which retards bacterial retting is acidity which is constantly removed when flax is retted in running water. Based upon this a process has been intro-

duced using a caustic alkaline bath which is tempered by the presence of organic matter such as the acid waste liquor from previous operations.

THE RESISTANCE OF TEXTILE FIBERS TO HIGH TEMPERATURES

IN the *Color Trade Journal* for November there is a note on the resistance of silk and linen to high temperatures and to ultra-violet rays. The work in question was done by M. Leo Vignon who exposed lightly stretched fabrics during June and July to such influences as solar light, dry heat, moist heat, moisture, obscurity, and the ultra-violet rays.

The results obtained indicate that the fabric of animal origin is more resistant to high temperatures and to ultra-violet rays than that of vegetable origin and the differences measured are thought to be due to the fact that the albuminoid molecule is more resistant to hydrolysis than the cellulose molecule. This explanation is in accordance with views previously held concerning the facility with which cellulose gives modified products, such as hydrocellulose and oxycellulose, whereas the animal fibers do not yield analogous products.

DETERMINING THE DEGREE OF SWEETNESS IN ARTIFICIAL SWEETENERS

SINCE artificial "sweeteners" (saccharin and dulcin) have become increasingly important from the economic viewpoint, a greater degree of attention deserves to be paid to the methods for determining the sweetening powers of these substitutes for sugar, since upon this their correct value and usefulness obviously depend. Measurements of this sort were long ago attempted but all authorities well know that up to the present there has been considerable uncertainty in this respect and that, at any rate, a generally known and practically applicable method has been lacking, and yet such a process is attainable by means of experimental psychology. The method in question being known as the "constancy" method which applies to stimuli of apparently equal effect, the stimuli, in this case being various degrees of concentration; this method yields results according to a definite formula equation (by Spearman-Wirth) of the stimulus value sought, *i.e.*, the sweetening power. The essential features of the process are as follows: Assuming that we wish to ascertain the sweetening value of those solutions of saccharin which correspond, judging by their taste, to a 2 per cent solution of cane sugar. We first prepare two solutions of saccharin, one of which is decidedly sweeter while the other is decidedly less sweet than the standard 2 per cent sugar solution. We next prepare a series of saccharin in solution, whose concentrations vary between the above limits, and which vary in equal degrees from each other. The examination made of these consists in a precisely regulated comparison of the sugar solution with each of the saccharin solutions, of which there are nine in all. The examination thus made must carefully eliminate all errors due to chance or irregularities. Moreover, a constantly increasing number of observers must take part at the same time in the experiment; this is probably in order to obtain a great many individual judgments, so that by the averaging of these individual errors may be excluded so far as possible. The temperature of the room and of the solution, as well as the time of day and the immediate surroundings, must be the same for all persons making the experiment. Each pair of solutions, *i.e.*, the sugar solution and one of the series of saccharin solutions is tested twice, the order being reversed the second time, by which means the influence of the so-called "position in time" is eliminated. A judgment must be expressed after every testing of the two solutions compared; this condition is required by the regard to the position in time as well as the deadening of the sensation and the fatigue otherwise involved. For the same reasons the solutions must always be tasted at a given word of command, so that all the time conditions of the observation are the same for all the observers. This applies especially to the intervals between the tests, during which intervals water, white bread, and red wine are taken, this likewise being done at the word of command. The different pairs of solutions can be tasted in any order desired, provided the same order in the series is followed by all the observers; sometimes the sugar solution is tasted first and again that of the saccharin takes precedence. In order to avoid the power of suggestion the solutions are given arbitrary figures. The data included in the judgments expressed comprise a statement as to which solution tastes the sweeter, whether they show an equality of sweetening power, and, finally, whether the tester is unable to decide between the two.

In a test of this kind in which three to four hundred judgments were expressed, these were first represented graphically. A certain regularity in their distribution is evident which is to be explained by the principles of the laws of probability. The formula equation chosen makes it possible to ascertain a definite zone for the judgment of equality. From this there is to be obtained likewise a definite chief value with higher and lower deviations therefrom.*

In numerous experiments of this sort, this process has given excellent results, as shown particularly by the amazing similarity of the values found. It should be remarked that this method is applicable, not merely to this particular case, but can also be readily applied to all related questions and its successful application strikingly exhibits the growing importance of the new science of experimental psychology.—An address delivered by Dr. R. Pauli before the congress of German naturalists and physicians in Nauheim, September 20-25, 1920. Translated for the *Scientific American Monthly* from *Die Umsau* (Frankfurt) for October 9, 1920.

TEST OF LARGE GRAIN HOPPER SCALE

THE importance of scales in every variety of business which is concerned with the buying and selling of commodities by weight is, of course, well recognized by everyone. In order to transact business on an honest basis, it is necessary that these scales be tested by someone in authority to determine whether they come within the required tolerances as to accuracy. Such work presents no particular difficulties when small capacity scales, such as are used in retail stores, are all that has to be considered. Many complications arise, however, in connection with the very large scales now used by the railroads and industrial concerns. The railroad track scale testing equipments maintained by the Bureau of Standards have been referred to in previous numbers of the MONTHLY.

Recently the Bureau conducted a test on a grain hopper scale of 120,000 lb. capacity located at Kansas City, Kansas. The work was done for the State of Kansas and other interested parties, including the Southwestern Milling Company, the Kansas City Chamber of Commerce, a number of railroads, the Western Weighing and Inspection Bureau, and the manufacturer of the scale. The test was one of the most thorough ever given to a scale of this kind. In addition to the ordinary testing, the dimensions of the scale parts were carefully measured and its capacity determined by means of computations based on these dimensions. Such work as this is of the greatest value to the public as it affects the buying and selling of very large quantities of grain and the wholesome influence of such a test, even when made upon only one of these large scales, is very important and nearly always results in the improvement of other scales in the vicinity.

As a part of the work in connection with the testing of a scale, the Bureau makes recommendations for the better maintenance of that particular installation and its recommendations have been followed to good advantage in nearly all cases.

*More precise details concerning this experiment, together with references to the sources of information, can be found in *Psychologisches Praktikum* (Jena), 1920, second edition.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

COOPERATIVE WORK IN CONNECTION WITH ELECTROPLATING

IT is to be regretted that many industries do not realize that a time of relative industrial depression is just the time to push investigational work. Ordinarily, when the demands for a product are very great, it is extremely difficult to carry out research work successfully, as all the energies of the manufacturer must be bent toward increased production. When business is dull, a comparatively small outlay may be wisely expended for industrial research, the fruits of which will be available when the demand for heavy production again occurs.

During the past month a member of the Bureau's staff has pointed out the importance of work of this kind in addresses delivered before three branches of the Electroplaters' Society. The importance of and possibilities for research in electroplating were pointed out and the desirability of conducting such work at this time, because of the reasons outlined above, was indicated. The close coöperation of the Bureau with the manufacturers and research men engaged in this industry should receive every encouragement as electroplating is an extremely important manufacturing process and has until lately received but little scientific attention. Through such meetings as the three just mentioned, the Bureau's staff is enabled to become better acquainted with those engaged in the industries and the problems which are in need of study. It is hoped that through such association it will be possible to make the work of the Bureau more immediately useful and also secure a more extended application of the results in everyday electroplating work.

THE CARBONIZATION OF LUBRICATING OILS USED IN INTERNAL COMBUSTION ENGINES

THE formation of the so-called "carbon" in automobile engines is one of the greatest sources of trouble for the average owner of a motor car. Much of this is attributed to the comparatively low grade of gasoline now available and some to the lubricating oil. A recent publication—Circular No. 99 of the Bureau of Standards—is devoted to this important subject. The nature and effects of the deposits formed in internal combustion engines are discussed and it is shown that the term "carbon" is a misnomer because the deposits consist largely of asphaltic matter. Brief accounts are given of the nature of petroleum oils and of the theories of formation of deposits. The oxidation and cracking of petroleum are discussed in detail. The next section of the circular takes up carbonization tests which depend upon oxidation and upon cracking, and full descriptions are given of the apparatus and procedures for the "Waters" and "Conradson residue" tests. Distillation methods are also touched upon and a general discussion gives brief summaries of certain controversial papers. and finally points out that there is yet much to be learned upon the subject of the lubrication of internal combustion engines.

TESTS OF LEATHER MADE FROM RABBIT SKINS

THERE has been received through the Bureau of Foreign and Domestic Commerce several samples of leather made from Australian rabbit skins. These samples were tested for tensile and tearing strength. The tensile strength was low, averaging from 800 to 1,200 lb. per sq. in. as compared with 4,000 lb. per sq. in. for calf skin leather. The leather also exhibited but little resistance to tearing. Some of the raw pelts were tanned in the laboratory by the one-bath chrome process, the resulting leather having about the same physical properties as the original samples. In general, the samples had many surface defects which would impair their cutting value and the small size of the skins would tend to cause considerable waste. However, it is thought that the leather could be employed for linings, novelties, and other similar work. A recent United States Consular report states that the leather has been used for shoe uppers.

HARDNESS OF STEELS PRODUCED BY ABRASION

THE relative hardness of various types of steels produced by subjecting all to the same abrading influences has been determined with the following results: In all cases except the high-carbon austenitic steel, no pronounced effect of the abrasion upon the steels used in these experiments was observed. In all cases the hardness of plain carbon steel is increased and among steels of this type the steel containing 0.85 per cent shows the greatest increase in hardness. The alloy steels generally show a smaller increase in hardness of abraded surface than plain carbon steels, and in some cases they show a decrease of surface hardness. High-carbon austenitic steel shows a marked decrease of Brinell and scleroscope hardness. The process of abrasion viewed in the light of Beilby's theory may be considered as resulting in the production of amorphous matter at the expense of crystalline matter which affects the hardness of the abraded surface of the metal but probably not the general character of its structure. As to the decrease of Brinell and scleroscope hardness of high-carbon austenitic steel, the following explanation may be suggested: According to Benedick's Pressure Theory, the martensite should be present in a greater amount on the lower layer of the examined specimen than in the inner portion and it seems possible that if the surface layer is ground away the next or more austenitic layer should be found to be somewhat softer.

TEMPER BRITTLENESS OF STEELS

AN extensive review of the literature on this subject has been made with the result that the nature and occurrence of temper brittleness may be summarized as follows: Certain steels which have been hardened by quenching from temperatures above the A_2 point and tempered at temperatures ranging from about 450 to 600° C. show low impact values if they are cooled slowly from tempering temperatures as compared with those cooled quickly. The cause of this phenomenon, which is also referred to as "Krupp Krankheit," has not yet been clearly established. The property of temper brittleness has been found present in carbon steels .25 to .4% C., nickel, chrome-nickel, chromium, and certain other alloy steels. Chromium-nickel steels of the same chemical composition and heat treatment have been found to vary widely in their susceptibility to temper brittleness and even in the opposite direction, *i.e.*, the slowly-cooled specimens were tougher than the quickly-cooled ones. The process of manufacture appears to have more of an influence than small changes in chemical composition, thus, steels made by the acid open-hearth process are more prone to temper brittleness than electric or crucible steels. The opinion has been advanced that the degree of work and the temperatures employed during the process of fabrication from the ingot bear some relation to the degree of susceptibility to temper brittleness. Other factors appearing to have an influence on the subject are the temperature of hardening preceding tempering treatment, degree of hardening, as cooling in water, oil, or air, the rate of cooling from tempering temperature, phosphorous content, and the furnace atmosphere

in which the material is treated. Other questions bearing upon the problem and upon some of which no general agreement has been reached and concerning which but little knowledge appears to be available are: relations between microstructure and susceptibility to temper brittleness, path of rupture, heating and cooling curves, relation between impact values and tensile test values as well as the Brinell hardness values, and the influence of the shape of the notched specimen upon impact test values.

CAUSES AND PREVENTION OF THE FORMATION OF NON-CONDENSIBLE GASES IN AMMONIA ABSORPTION REFRIGERATION MACHINES

TECHNOLOGIC PAPER No. 180 on this subject has recently been issued and may be secured in complete form from the Superintendent of Documents, Washington, D. C., at a cost of 5 cents per copy. The paper may be summarized as follows:

In the experiments conducted at this Bureau, the conditions existing during the operation of an ammonia absorption refrigeration machine were duplicated. It was found that the presence of the non-condensible gases that cause so much trouble in the operation of these plants is due to either of the following causes: (1) leaks of air into the system, and (2) the corrosive action of the aqua ammonia on the metal of the plant.

If the foul gas is mainly nitrogen, the gas is derived from the air that is leaking into the system. The oxygen originally present in the air is quickly used up when the plant is operated and so will be present in only a very small percentage of its original amount. On the other hand, if the foul gas is hydrogen, the cause is corrosion by the ammoniacal liquor. Pure aqua ammonia will not cause gas formation but if salts of such weak acids as acetic or carbonic acid are present in the aqua, the corrosive action will continue during the life of the charge. If the gas in the plant contains both nitrogen and hydrogen, both causes are present.

The corrosive action of impure aqua may be completely stopped by the addition of either sodium or potassium dichromate to the aqua in the plant. The dichromate is conveniently added in the form of a concentrated solution and gas formation will be stopped if the salt is added to the extent of .2 per cent of the weight of the aqua present. It is best to add the dichromate to the charge in all plants as its presence decreases the very small amount of gas caused by even the highest grade ammonias.

THE YEAR'S PROGRESS IN RADIO TELEPHONY

THE Radio Section of the Bureau has for some time devoted a great deal of attention to radio telephony and as the year closes it is of interest to note the progress which has been made in this art, both in the Bureau's laboratories and elsewhere. The past year has witnessed steady progress and increasing public interest in radio telephony, and voice transmission by radio waves has advanced from the experimental stage to established practice for distances of a few hundred miles. All inherent difficulties have been surmounted so that it is possible to carry on reliable radio telephony over as great a distance as ordinary wire telephony and it seems entirely probable that the transmission of speech commercially across the Atlantic will be an established fact in the not far distant future. The quality of transmitted speech or music by this means is as perfect as in ordinary wire telephony.

The essential characteristic of radio telephony is the use of high-frequency waves which act as carriers for the relatively low-frequency current which reproduces the sound alternations. The carrier-waves may be radiated into space in all directions or may be guided along conductors. Furthermore, radio ar carrier-wave telephony may be linked with or connected to ordinary wire telephony. These developments unquestionably point to the supplementing of the ordinary systems of telephony by radio methods.

DEFINITIONS AND SPECIFICATIONS OF LIME

A PREVIOUS publication on this subject has already been referred to in the MONTHLY. Circular 106 is now ready for distribution by the Superintendent of Documents, Washington, D. C., at 5 cents a copy. It contains briefly the following information:

Limestones are classed as high calcium or magnesiam according to the ratio of lime to magnesia which they contain. According to their physical structure, they vary from marble to chalk. Crushed stone of various sizes is used for blast furnace flux, aggregate for concrete and asphalt, ballast, road metal, sand, whiting, etc. It is also a basic raw material used in the manufacture of cement, glass, pottery, and many other things. Agricultural lime used as a fertilizer may be ground limestone, quick lime, or hydrated lime. Quick lime is made by burning limestone. It is used as a building material and as an ingredient of mortar and plaster. Slack lime is made by adding water to quick lime to form a body. Hydrated lime is made by adding just enough water to quick lime to form a dry powder. It is used as a building material instead of quick lime and also as an addition to cement, mortars and concretes. Both quick lime and hydrated lime are used as basic raw material in the manufacture of paper, sugar, bleaching powder, alkalis, etc. Air-slacked lime is worthless as a building material and is seldom an article of commerce. Quick lime is shipped in barrels holding 180 or 200 lb. and hydrated lime in paper bags holding 50 lb.

The circular describes the quantity of lime required for making plaster and mortar as well as the amount for use as fertilizer. A formula for making whitewash is likewise included. Hydrated lime should contain not more than 5 per cent impurities nor 3 per cent carbon dioxide. It should be of such fineness that not more than ½ per cent shall remain on a No. 30 sieve nor more than 15 per cent on a No. 200 sieve. It should pass the prescribed steaming test for soundness.

THE MAGNETIC TESTING OF TWIST DRILLS

THE determination by magnetic tests of inhomogeneities in steel is a new method which is now assuming considerable importance. During the war the Bureau developed an arrangement by which imperfections in rifle barrel steel could be easily detected, thus allowing the manufacturer to throw aside any imperfect material without having to wait until the same had been subjected to a finishing process to discover the flaws.

Within the past month the Bureau has commenced a cooperative investigation with one of the committees of the American Society for Testing Materials on the testing of twist drills by magnetic analysis. One of the members of the committee has prepared the steel by a special process and the test for homogeneity will be made by the magnetic method developed at the Bureau. The drills are to be manufactured by another member of the committee under carefully controlled conditions and will again be tested magnetically. After the drills have been finished, they will be returned to the manufacturer who is to subject them to a thorough mechanical test. After all these data have been secured, the committee will meet and attempt to find whatever correlation may exist between the mechanical performance of the drills and the results of the magnetic analyses. The ultimate object of this investigation is the development of apparatus which can be used in a commercial way for the non-destructive testing of twist drills.

RECENT PUBLICATIONS ON PAINT

THE following Bureau of Standards circulars are now ready for distribution and may be bought from the Superintendent of Documents, Washington, D. C., at 5 cents a copy:

Circular 102.—Recommended Specification for Composite Thinner for Thinning Semi-paste Paints When the Use of Straight Linseed Oil Is Not Justified. Circular 103.—Recommended Specification for Spar Varnish. Circular 104.—Recommended Specification for Asphalt Varnish. Circular 105.—Recommended Specification for Liquid Paint Drier.

Notes on Science in America

Abstracts of Current Literature

Prepared by Edward Gleason Spaulding, Professor of Philosophy, Princeton University

OPTIMUM NUTRIENT SOLUTIONS FOR PLANTS

DURING recent years numerous investigators have devoted considerable time and resources to the study of the salt requirements of various plants. Plans have been proposed for the extension of this work, with the hope that certain fundamental data may be obtained which shall indicate the composition and concentration of the solution or solutions best suited to the growth of the plant. It now seems to be an opportune time to raise the following questions: First, it is probable that the plant has any definite response within broad limits, to a particular ratio of salts or ions contained in the complete nutrient solution; and second, assuming the existence of such optimum solutions, are the methods generally employed adequate to determine their composition?

During the course of an investigation on certain phases of plant nutrition, an experiment has been carried out in connection with the first point. Three series of nutrient solutions were prepared containing different percentages of K, Ca, Mg, PO_4, NO_3, and SO_4, and measurements were made of total weights and average lengths of tops and roots.

The experiment showed that solutions of radically different concentrations and salt proportions do not affect the yield of the crop to any important extent. This does not mean, however, that certain solutions (possibly including those containing large proportions of magnesium salts) may not inhibit plant growth because of unfavorable physiological balance. The point which it is desired to make is that the range of equally favorable ratios between nutrient salts is probably a very broad one, no doubt including the solutions of most soils. This conclusion is not surprising in view of the observation that under proper climatic conditions many different types of plants can grow vigorously on any fertile soil, while a given type of plant may grow equally well on various soils, the extracts of which have entirely different proportions of nutrients. Again, plants of equal development may store nutrient elements in very different ratios, when grown in different soils or solutions.

It has sometimes been suggested that solution and sand culture experiments offer a fundamental means of determining fertilizer requirements of soils, in connection with a proper physiological balance for the plant. If one considers the dynamic nature of the soil system, with its constantly fluctuating soil solution and the reactive properties of the soil minerals, it seems scarcely within the limits of possibility to alter a soil solution to fit any particular ratio of nutrients. The addition of any one fertilizer salt may affect all the various components of the soil solution. Moreover, many elements are present in the soil solution besides those added to the artificial culture solutions and it may not be assumed that these are without effect on the physiological balance of the solution, if indeed such a balance is of importance ordinarily.—Abstract from an article by D. R. Hoagland of the Division of Agricultural Chemistry, University of California in *Science* for December 10, 1920.

THE ABSORPTION-TRANSPIRATION RATIO IN PLANTS

IN *Science* for November 26, 1920, Mr. E. S. Johnston of the Maryland Agricultural Experiment Station directs attention to a method of studying the absorption-transpiration ratio in nutrient media.

Several writers have shown that the water content of plants varies with the hour of the day. This variation is of course due to differences in the rates of water entrance and exit. Wilting takes place when the ratio of the rate of entrance to the rate of exit is less than unity whether caused by excessive transpiration or by a decrease in root absorption. These two plant processes may easily be studied by using water culture plants exposed to different environmental conditions or placed in solutions of different osmotic pressures. The following experiment was made by Mr. Johnston to illustrate the manner in which changes in the strength of solutions affect the ratio of absorption to transpiration:

The roots of a tomato plant were passed through a hole in the rubber stopper of a large mouth bottle of about 600 cc. capacity. A watertight seal was made around the stem of the plant; a 2 cc. pipette, graduated to 1/20 cc. and a thermometer were inserted into the bottle through the stopper. The bottle and pipette were then filled with the nutrient solution, care being taken that no bubbles were inclosed beneath the stopper. Loss in weight of the plant and container gave the amount of transpiration, while the loss of solution from the pipette gave the amount of root absorption after temperature corrections were made. These corrections were made by comparing the pipette readings with those of a pipette in a similar bottle containing no plant, but exposed to the same set of conditions. Transpiration was measured in grams while absorption was measured in cubic centimeters, but as the variations in density of the solutions for these temperature ranges were small in comparison to the actual values dealt with this correction was not made.

The following table gives the data showing rates of transpiration and absorption of a tomato plant with roots immersed successively in a three-salt nutrient solution of 1.75 atmospheres osmotic pressure, cane sugar solution of 5.06 atmospheres osmotic pressure, and distilled water:

Period	Hourly Rate of Transpiration gram	Hourly Rate of Absorption cc.	Ratio A/T	Solution and Osmotic Pressure
1	.41	.44	1.07	3-salt, 1.75 atm.
2	.31	.37	1.19	3-salt, 1.75 atm.
3	.42	.28	.67	Sugar, 5.06 atm.
4	.29	.18	.62	Sugar, 5.06 atm.
5	.41	.46	1.12	Distilled water
6	.32	.39	1.22	Distilled water

When the hourly rate of absorption is in excess of transpiration the ratio, A/T, is greater than unity and the plant cells increase in turgor. When this rate is less than unity turgor is decreased and if the process is continued long enough the cells become flaccid and the plant is seen to wilt. The plant gained in turgor during the first two periods given in the table, but during the third and fourth periods the ratio values decreased very much. This decrease was mainly due to lower absorption rates since the roots were surrounded by a solution much stronger osmotically during these two periods than during the first two. The rates of absorption for the last two periods were greatly increased by placing the roots in distilled water.

THE COMPOSITION OF GASES IN RIPENING FRUITS

A STUDY of the ripening processes in fruits and of the chemical and physiological changes associated with them, raises the question as to what may be the composition of the gas in the intercellular spaces. The gas within the tissues constitutes in part the medium in which the processes associated with the life of an organism take place. It is only reasonable to suppose that the composition of this medium may exert some influence upon the rate or nature of the changes taking

place. However, owing to the difficulty of extracting the gases from the interior of the tissues plant physiologists have almost entirely neglected studies along this line.

An apparatus has been devised for obtaining a sample of the gas from within the tissues without contamination with air. The use of this apparatus showed in the case of Yellow Newton apples, that the percentage of CO_2 in the gas within the tissues increases markedly at higher temperatures, at the same time that there is a corresponding decrease in the percentage of oxygen present, the average ranging from 142 per cent at 2 degrees C. to only 3.2 per cent at 30 degrees C. The data collected, representing averages of a number of determinations, clearly indicate that a marked variation may occur in the composition of gas in the tissues under varying conditions of temperature.

Three main factors are found to operate to determine the amounts of CO_2 and oxygen in the intercellular spaces at any given temperature. These are (1) the rate of oxidation, or the rate at which oxygen is taken up from, and CO_2 given off into, the intercellular spaces; (2) the permeability of the skin or epidermal covering to CO_2 and oxygen; and (3) the difference in pressure of CO_2 and oxygen within and without the fruit, which determines the rate of gaseous exchange when the permeability factor is constant. The effect on each of these factors of varying the temperature will explain the variation occurring in the internal atmosphere of the tissues studied at the different temperatures.

From a consideration of these relative effects of temperature on oxidation and on permeability, it is apparent that the absorption of oxygen and release of CO_2 are increased much more by a given rise in temperature than in the tendency for oxygen to be supplied to the tissues, and CO_2 to be given off from them. Consequently, as the temperature is raised, the amount of oxygen in the tissues becomes less and less, while the CO_2 accumulates correspondingly. This continues until the third factor becomes effective, that is, the difference of CO_2 and oxygen pressures within and without the fruit becomes so great that equilibrium is again established.

No attempt has been made in this preliminary work to associate the percentage of CO_2 and oxygen found with the processes taking place in the fruit. The data presented, however, clearly indicate the necessity of taking this factor into consideration in many types of horticultural and physiological investigations. It should be given attention in studies of the effect of temperature upon the processes in plant tissues, for it is readily apparent that much variation may be caused by the composition of the medium in which these processes are carried on. Of special importance is the application of studies of this type to the questions as to the effect of wounding and various other treatments on the respiratory processes in tissues. Finally, it is of prime importance to know the composition of the internal atmosphere in studying the effects of various gases, etc., on plant organs. Some work has been done on the effect of various gases on fruits and vegetables in storage. Obviously, it is essential in such work that the composition of the internal atmosphere be known.—Abstract from article by J. R. Magness in *The Botanical Gazette* for Oct., 1920.

MENTAL TESTING AND THE EDUCATION OF HANDICAPPED CHILDREN

IN a long article published in a recent number of the *American Journal of School Hygiene*, Dr. J. E. Wallace Wallin, director of the Psycho-Educational Clinic of the St. Louis Public Schools, discusses the general problem of Handicapped Children.

As showing the seriousness of this problem, Dr. Wallin says that many years of experience in examining children in the St. Louis public schools has led him to believe that the percentage of feeble-minded children in the elementary schools of this system is about one-half of one per cent. An estimate which agrees with Dr. Walter Cornell's estimate for the Philadelphia schools and Dr. Clara Schmitt's estimate for the Chicago schools. If this ratio held throughout the country there would be over 102,000 feeble-minded children in the public and private elementary schools of the United States.

Dr. Wallin's experience in the St. Louis public schools further indicates that for every feeble-minded child there are from five to ten children on the borderline of mental deficiency who require individual and differentiated instruction in ungraded classes and elementary industrial schools. The assumption is probably conservative that at least 3 per cent of elementary pupils throughout the country classify in this group, giving an estimate of over 615,000 pupils (aside from the feeble-minded mentioned above) who are too backward to do successful work in the regular grades.

Concerning the educational methods to be used in meeting the problem of these subnormals Dr. Wallin finds that they are most successfully trained in centers apart from the elementary schools and apart from other types of special classes, such as the classes for incorrigible, truant or backward pupils. No child should be assigned to a class for the feeble-minded unless he has been properly certified as a result of a careful investigation of his history and present mental and physical condition. It is most important that the child be given a careful psychological examination. The majority of candidates should be tried out in the kindergarten and first grade before they are reported, while children who cannot be definitely certified as a result of the examination to be mentally defective, should be given the benefit of the doubt and be assigned to ungraded classes for further trial under most favorable conditions.

The curriculum for mental defectives should include the rudiments of the literary branches, which should be presented concretely and in correlation with practical industrial problems; sensorimotor exercises; industrial training; physical training; moral training, mostly habituation in correct modes of response; speech improvement and correction; and musical training. The guiding aim of the program of studies in the special school for mental defectives should be distinctly practical rather than cultural.

NEW FIELDS OF PHYTO-CHEMICAL RESEARCH

DR. EDWARD KRAMERS in the October number of the *Journal of Industrial and Engineering Chemistry* points out how the cultivation of medicinal plants on an economical scale as has been done at the Wisconsin Pharmaceutical Experiment Station presents new opportunities for research, particularly regarding milling and distillation problems. As Dr. Kramers points out a scientist who has conducted experiments on a laboratory scale finds a new set of problems confronting him when he undertakes to distil the plants from an acre of peppermint or to mill half an acre of belladonna plants. The author records the observations of a scientist pointing out that while some of the problems overcome may be old to the technologist, the technologist does not frequently record his experiments for the benefit of the scientist, so that any record of scientific observation is of value. He says: "If it required years of study to isolate and identify the oily constituency of plants it will no doubt require years and years to study their water soluble voluble constituents. If for years the writer has desired to devote to these latter constituents such attention as they seem to merit he has also wanted for the same length of time to study those products which escape from the condenser and are not collected either in the separated oil or the aqueous cohobates. The study of these escaping vapors will require, as experience has already shown, especially constructed condensers and absorbers. Thus will be trebled in size as it were this one field of phyto-chemistry." It is evident that if plant chemistry is to advance in this country the biochemical study of the plants and the study of the problems involved in large technological operations must go hand in hand.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

By H. E. Howe, Member of American Chemical Society

RUBBER ANALYSIS

THE *Chemical Bulletin* for December printed an article by John B. Tuttle on "The Interpretation of Rubber Analysis." The constituents of rubber compounds can be classified as rubber, sulphur, accelerators, and fillers, and an analysis of rubber compounds should be designed to develop the facts regarding these groups and the significance of these facts should be determined by experienced chemists. At present the principal tests are acetone extract, chloroform extract, alcoholic potash extract, ash, total sulphur, free sulphur, mineral and organic fillers, with special methods for the detection and determination of oils, glue, paraffin and the like. Fatty oils such as palm oil and cotton seed are probably added for their softening effect, but mineral oils usually denote reclaimed rubber. Paraffin wax is used to close up minute pores in the rubber for insulated wire. The various extracts named are for the purpose of separating the constituents soluble in the reagent used. Thus the acetone extract may contain resinous matter from the crude rubber, the free sulphur oils and waxes. The rubber resins run about 2 to 4 per cent in high grade material and a higher percentage indicates low grade or reclaimed rubber. The expert is guided in judging the grade of rubber used by the properties of these rubber resins. The chloroform extract brings out the bituminous substances. It is only qualitative, but the results it yields are important. The alcoholic potash dissolves the oil substitutes and if an amount greater than one per cent of the rubber present is found the use of oil substitutes is indicated. The interpretation of ash is difficult for some fillers enter into new compositions on heating and others are more or less volatile.

The usual practice is to obtain the percentage of rubber by difference and while its actual determination is important it is seldom made. This is largely due to the difficulty of making an accurate determination and a great deal of time has been spent in an effort to develop a satisfactory method.

The various methods are not as accurate as might be wished and the results of any analysis should be accompanied by reference to the methods by which they were obtained. The interpretation of the analysis cannot be made without careful consideration of the methods, the probable error which they involved, the purpose for which the article is to be used and some knowledge of the effect of the various constituents upon the service which is expected.

A NEW MOTOR SPIRIT

MUCH has been written on this subject and Dr. Juritz in *Journal of Industries* (South Africa) briefly reports the result of researches by S. W. Blake, which has led to a patentable process yielding fuel known as acetol although that word already has a specific meaning in chemistry, being applied to an organic substance. While full details are not yet available it is reported that the object of Mr. Blake's invention is to make possible the blending of acetylene gas with alcohol through the use of a second solvent. In discussing the use of alcohol, which is more satisfactory when mixed with other fuels, it is pointed out that more recent efforts have been directed toward finding a substance which would be more effective and less expensive than ether, and since a liquid like ether forms an efficient mixture with alcohol because it is so easily converted into a volatile highly combustible vapor it seemed rational to introduce a ready formed inflammable gas in large proportions into the alcohol. Acetylene suggested itself because it is highly explosive when mixed with air and apparently does not injure the metals and oils of the engine. Now alcohol and ether can be mixed with each other in any proportion, giving a gradation to meet the variety of requirements, but if acetylene is substituted for the ether this latitude of grading becomes impossible since a point is reached beyond which the introduction of acetylene gas into alcohol gives proportions which refuse to mix, six parts by volume of acetylene to one part of alcohol being the limit.

At this point Mr. Blake conceived the idea of using with the alcohol a second solvent in which liquid acetylene might dissolve more readily than in alcohol, and ultimately he found a liquid which can be added to alcohol in any proportion and a certain mixture has the ability of absorbing from three to four times the quantity of acetylene that alcohol can absorb alone.

As to the economic success of this method one must await the disclosure of further details, particularly those concerning the possible supply of the second solvent mentioned and the price which consumers can afford to pay for such a new fuel based upon the service which it is capable of rendering.

WHITE SUGAR IN NATAL

AT least one mill in Natal is operating the combined beet and cane sugar process which produces a sugar nearly equal to white refinery sugar direct from cane juice and with a greater recovery than has been experienced heretofore. Carbonization, which has always been a feature in the production of sugar from beets, is introduced in the treatment of raw cane juice and both a first and second carbonization are employed. A light colored syrup is obtained free from suspended and viscous matter; the time of boiling to grain is shortened by 20 per cent; a better separation of crystals from the molasses is secured; and there is an increase in the recovery of brilliant white sugar. The process enables the mills to use a greater amount of South African material, thereby reducing the imports of foreign chemicals tends to somewhat increase the food supply and is a further step toward self-dependency.

FORMALDEHYDE AND METAL CORROSION

IN the December *Journal of Industrial Engineering and Chemistry* there is reported a series of results undertaken to determine to what extent a small amount of formaldehyde in acids might inhibit the solution of the metal in the acid. Several grades of steel as well as wrought and cast iron were employed in the tests and it was found that the presence of one per cent of formaldehyde in a ten-degree B. sulphuric acid and also in a 1:1 hydrochloric acid solution decreases the solvent action of these acids to a marked degree especially in the case of wrought and cast iron and steel. The effect is less marked with 10 per cent nitric acid. The use of muriatic acid containing about one per cent of formaldehyde affords a convenient means of pickling rusty steel without appreciably affecting the surface of the steel.

STEEL WIZARDS, PAST AND PRESENT

THIS was the subject of Dr. Saveur's address before the American Society for Steel Treating at its last annual meeting. In his address Dr. Saveur brings together in a useful way many facts concerning the contributions of pioneers in steel making in the past and includes in his review reference to appliances which have played such an important part along with chemistry.

Among the Americans who are entitled to a place because of their notable inventions, discoveries or improvements in the

art of making wire or heating iron and steel or for scientific contributions to that art, the following are named: Campbell, who designed the first tilting open hearth furnace; John Fritz, the inventor of the three-high rolling mill; James Gayley, for conceiving and executing the dry air blast, which has been such an economic factor in steel making through the conservation of fuel; A. L. Holley, whose improvements in the construction of Bessemer Mills were notable; Henry M. Howe, whose contributions to our knowledge of steel have been invaluable. The use of mixers in steel making was introduced by W. R. Jones. High speed tool steel was discovered by F. W. Taylor and Maunsel White. Many useful appliances including charging machines and the improvements in the construction of open hearth furnaces are attributable to S. T. Wallman; and Frederick W. Wood introduced the car casting method for making steel ingots.

The address in full will be found in the November issue of the transactions of the American Society for Steel Treating.

NAVAL STORES

IN the November number of *Chemical Age* (New York) Mr. J. F. Carter, Jr., contributes an article under the title. "Plain Talk on Pine Stump Naval Stores Recovery." "At no time has there been so great a need as there is today for active military development of the processes for extracting the naval stores, turpentine and resin, from the stumps on the cutover lands of the long leaf yellow pine section of the South." Mr. Carter discusses the process by which such great quantities of cutover lands have come to lay idle and points out that much money has been lost in an effort to extract the turpentine and the resin from the stumps. There have been many failures most of which appear to have been due to a lack of adequate chemical knowledge. The extraction of naval stores from yellow pine stumps is strictly a chemical problem. Without good chemical advice the products obtained by most of the processes are so impure as to render them of low value, if indeed not valueless.

Destructive distillation is very sure to yield impure products at every step, due to the impossibility of control and the mixture of resins and ligneous products which come over. Steam distillation comes next in the scale. It takes out a large part of the turpentine, but not all, and leaves all else behind. Mr. Carter believes that steam distillation could only succeed in days of high priced turpentine. In the use of the less volatile solvents such as gasoline, benzine, naphtha, and carbon bisulphide, with the expense of the equipment and the recovery of the solvent as a drawback, there is necessarily a certain percentage of the solvent lost and the slowness with which the process can be carried out introduces an inconvenient time factor.

Mr. Carter then describes a process which he has worked out after some 17 years and he has given the name Triple Alkaline System to his method. Turpentine is recovered as pure turpentine, resin in the form of resins which can be distilled to get the various grades which the market demands, and chemicals employed recoverable with small loss.

DETECTION OF OILS OTHER THAN LINSEED IN PAINTS

BEGINNING on page 1189 of the December issue of the *Journal of Industrial Engineering and Chemistry* there is a discussion of the possibility of detecting oils other than linseed in paints by means of the hexabromide number of the fatty acids. The work is based on that reported by Steele & Washburn some time ago and is aimed at the simplification of the process reported. The article to which reference is made gives detailed description of the method and details of results obtained on pure linseed and other oils; such as soybean, tung, menhaden and mixtures of linseed with soybean oils. The authors give the following summary:

"A method has been developed for the detection of substitutes in linseed oil and paints based upon the determination of the amount of ether insoluble hexabromides by brominating the fatty acids under fixed conditions. The method is less complicated than some of those previously proposed and gives more concordant results. The hexabromide value of pure extracted or expressed linseed oils varies between comparatively narrow limits and is on the average about 42. The average hexabromide value of pure soybean oil is 6, and of tung and fish oils, zero. The latter, however, gives ether insoluble octobromides which can be readily separated from the hexabromides of the vegetable oils because of their insolubility in warm chloroform.

"The proportion of linseed oil in a mixture of soybean, tung, or fish oils can be determined much more closely by means of the hexabromide than by the iodine value of that mixture. It appears probable that by the method developed a close approximation of the composition of the unknown volatile vehicle of a paint may be obtained, but further study of the applicability of the method to paint analysis is desirable."

CEMENT FOR PORCELAIN

THE November *Journal of the American Ceramics Society* contains among its abstracts the following suggestion as to cement for porcelain. These cements are used in cementing porcelains and metal. The first is composed of ground flour spar, finely powdered glass and sodium silicate, commonly called water glass. The old standby, litharge, made into a paste with glycerine, is the second on the list. Another suggestion is a thick glue mixed with one-half part of boiled linseed oil. Another is zinc oxide, calcined magnesia, and sodium silicate in equal parts. This mixture should be dried slowly. Chalk or precipitated calcium carbonate and powdered zinc mixed in equal parts with sodium silicate is another formula. The final is 20 parts plaster of paris, 50 parts of fine ground flint and 30 of zinc oxide. This mixture is made into a thick paste with sodium silicate.

RESEARCH IN SOUTH AFRICA

IN the *Journal of Industries*, which is published by the Union of South Africa, a recent number reports industrial research in the Union which was being carried out by the Advisory Board of Industry and Science. The accomplishments include the commencement of the following special surveys: mineral, botanical, fisheries, waterpower, soil and zoölogical. Scholarships have been established for the encouragement of the study overseas by young South Africans especially in the subjects of commerce and industry. A technical officer has been appointed to the Department of Industries and the scientists have had a part in developing a scheme for the establishment of a permanent tariff board with the object of creating an elastic and scientific system of tariff to insure suitable conditions for the extension of the industries of the Union.

The Advisory Board is to be succeeded by the Department of Industries.

PETROLEUM REFINING PROBLEMS

H. M. HILL, Chemical Engineer of the Bureau of Mines, under the title, "Refining Problems of the Petroleum Industry" in *Chemical Age* (New York) for November, emphasizes the fact that most of the problems in the industry are of minor importance when compared with the serious problem, that of obtaining adequate quantities of crude petroleum, and points out that the skimming plants that now surround the older producing fields have a difficult problem to face. The larger refineries at the terminals of trunk lines or those that have their own production are not likely to be so greatly affected by conditions which made the refineries in operation in 1918 and 1919 capable of refining more crude oil than is produced in our country.

Mr. Hill discusses the types of refineries, the topping plants where the lighter fraction is removed from the crudes and the skimming plants which remove only the lighter fractions from crude petroleum. Complete refineries are those that

manufacture lubricating oils in addition to the products produced by the skimming plants. Some refineries are equipped with cracking plants.

The five major products derived from petroleum are discussed at some length, these being gasoline, kerosene, lubricating oils, gas oil and fuel oil.

A great deal of constructive work will be expected of the American Petroleum Institute recently established to promote research and other constructive work in the petroleum industry for the solution of some of these pressing problems.

NEW FIBERS

IN the December 22nd issue of *Chemical and Metallurgical Engineering* appears an account of a new German vegetable fiber industry which is centered in the plant of the German Fiber Material Company established in 1912. China grass, Australian seaweed, and jute have received the most attention. The vegetable fiber derived from the China grass is known as solidonia and is similar to ramie. By a secret process a long, stout, fine fiber is made from this grass, the curliness being a special feature. This makes it possible to mix quantities of the fiber with wool and it has been used extensively in underwear and woolen goods. Since it does not shrink as does wool it has a certain value in the manufacture of underwear.

Solidonia has been used in Germany for the manufacture of table linen, hosiery, which are difficult to tear, machine belting and sporting jackets. The army cloth, composed of 75 per cent wool and 25 per cent solidonia, is said to surpass in tensile strength any pure wool cloth. Much of the material has been used in the United States.

Another fiber called posidonia is derived from Australian seaweed. This is said to be equal to medium staple wool and it is spun on the worsted and the woolen system. The fiber is elastic and springy and the cloth made from it without the mixture of other fibers shows little if any creasing. It is said to be well suited to carpet manufacture and before the war sold at half the price of shoddy.

It is claimed that a special chemical process produces a long, fine, beautiful fiber from jute having characteristics enabling it to be spun on the worsted system pure or mixed with wool. Beginning with the manufacture and sale of fibers, the company in question has now extended its activities to spinning and may presently engage in weaving.

FORMALDEHYDE IN LEATHER MANUFACTURE

As long as 20 years ago formaldehyde solutions of about .3 per cent were used for preserving hides but such hides then required the use of sulphurus, formic or other weak acids to the soaks and of sulphide to the limes. A plumper leather is obtained by swelling the hides with acid after they have come from the stick vats and then fixing this swelling by treatment with formaldehyde. After this treatment, the tanning may be completed in strong rocker liquors followed by drumming but without the usual disadvantages. Formaldehyde is also used in fixing the hair of fur skins and is sometimes employed for stiffening the grain of loose hides. If tawed skins are treated with formaldehyde, then neutralized, washed, fat-liquored and bleached they are made resistant even to hot water. A complete article on this subject is to be found in *Le Cuir*, IX, 229-32 and 242-46 (1920).

THE HIGHER ALCOHOLS

A NOTE has been made elsewhere concerning the importance of the organic chemical industry, and in nearly all work in that field the various alcohols of high purity are of greatest importance. The manufacture of such refined reagents and related substances is therefore of interest. One of the largest companies interested in the production of alcohol has begun the preparation on a commercial scale of refined alcohols, acetates, and ethers.

There is a considerable series of alcohols, the first two of which are the ones with which most people are best acquainted. Methyl, or wood, alcohol is the first of the series followed by ethyl, or grain, alcohol. If we write the arrangement of the atoms for the first we find it to be a carbon atom with which three hydrogen atoms and one hydroxyl (OH) group are connected, while the second consists of carbon with the three hydrogen atoms linked with a second carbon, holding two hydrogen atoms and the hydroxyl group. This gives us the beginning of a chain which may be extended until there are many carbon atoms, the first holding three hydrogens, the last, two hydrogens and a hydroxyl group, and the ones between connected with a carbon atom on each side and a hydrogen atom both above and below the line. Thus we have the so-called higher alcohols such as amyl, butyl, propyl, etc. The acetates and the ethers have their starting point in these various alcohols.

The alcohols are commercially important; thus isobutyl alcohol is a starting point in the manufacture of artificial musk. Ethyl aceto-acetate is important in the manufacture of tartrazine, an important dye material. Heretofore, the difficulty of obtaining some of these compounds has retarded certain important research activities, so that chemists are glad to know that amyl alcohol, isobutyl alcohol, normal propyl, and the like are now available in addition to anhydrous methyl alcohol, analyzing from 99.7 to 100 per cent CH_3OH. Besides these, anhydrous ethyl acetate, ethyl aceto-acetate, and anhydrous methyl acetate are to be had. This list will doubtless be considerably extended and amplified in the near future.

BLAST FURNACE SLAG

A CERTAIN amount of blast furnace slag is utilized in the preparation of cement; but the possibility of molding this material into a variety of forms has always been attractive, and a British patent has now been granted T. F. Hoere which relates to the utilization of blast furnace slag in the production of bricks, blocks, tiles, and various other parts of buildings. The patent is abstracted in the August 25th number of *Chemical and Metallurgical Engineering* which states that, in addition to various uses in dwellings, the patent covers electric insulators, electric main conduits, the bed plates of electric generators, curbing, tanks, etc. Some inventors have had the idea that the molten slag might be immediately conveyed to an adjacent plant and molded without reheating, thus saving fuel costs; but the patent in question calls for breaking up the cold slag after which the particles are packed in the molds and the molds are then filled with a molten slag so as to bind the particles of graded slag together. The graded slag may be heated and the molten slag mixed with 10 to 15 per cent of silica, lime or other binding agents. Various oxides are used for coloring purposes. While in the molds the product may be heated and cooled to anneal it, and if for any reason molten slag direct from the blast furnace cannot be used the molds may be filled with the graded slag, mixed or not with such materials as soda, ash, cryolite, broken glass waste, etc., having a lower melting point than the slag and afterward heated to a temperature above the melting point of the slag. Various other ways of using the graded broken slag and the molten slag are covered in the patent.

FORMATION OF FERROUS SULPHIDE IN EGGS DURING COOKING

IN the *Biochemical Journal*, Vol. 14, 1920, Tinkler and Soar report their finding that the greenish black coloration on the surface of the yolk of a hard boiled egg is due to the formation of ferrous sulphide. The sulphur compound in the egg white is probably decomposed, giving rise to hydrogen sulphide, which forms the ferrous sulphide. The decomposition of this sulphur compound may be checked by simply cooling the egg immediately after boiling, in which case the objectionable coloration does not occur.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

By A. Slobod

RECENT PROGRESS IN METAL SPRAYING

Previous to the war the Schoop process of metal spraying was applied in this country primarily for obtaining protective coatings. References to the early literature on this subject will be found in the bibliography published by the Carnegie Library of Pittsburgh, entitled "Metal Corrosion and Protection" and in its supplement published in 1915 in Proceedings of the Engineers Society of Western Pennsylvania. A chapter on this subject will also be found in the book by Flanders—"Galvanizing and Tinning."

During the war and after the Schoop process has made great strides in Germany. An electric pistol has been developed. The metal to be squirted is heated by means of an electric arc. Details are given in *Elektrotechnische Zeitschrift* for January 16, 1919, *Elektrotechnik und Maschinenbau* for January 5, 1919, as well as in the book by W. Kasperowitz and M. V. Schoop, entitled "Das Elektro-Metallspritzverfahren" (Carl Marthold, Halle a. S., 1920.) Its sphere of usefulness has been extended to include not only metal protection but also many operations formerly performed by soldering or brazing as well as all those cases where a metallic layer of one kind or another is desired. In the electrical industry, for instance, condenser plates could be prepared by depositing metal on glass; imperfect electrical contacts are eliminated; in the armature construction it could be used as a substitute for soldering and brazing; carbon electrodes or brushes could be firmly attached to the metal terminals; insulators may be coated with metal so as to improve in certain places the distribution of the electric field; light accumulator plates may be constructed by deposition; electric heating units can be manufactured by spraying the metal into proper forms; gloves, masks and wearing apparel in general can be covered with a layer of lead as a protection against the action of Röntgen rays or radium rays. These and many other possible uses are described in the book by Schoop which appeared last year and which is entitled "Das Schoopsche Metallspritzverfahren."

It is also interesting to note a paper by Robert Hopfelt in *Zeitschrift des Vereines Deutscher Ingenieure* for July 24, 1920, in which he gives a critical review of some of the recent applications of the Schoop process. He finds that the main drawback in many cases has been the porosity of the metal layers. Best results are obtained with zinc, lead and aluminum as coatings, while metal spraying upon wood, paper and textiles has not proven to be satisfactory.

The Schoop apparatus were handled in this country by the Metals Coating Company of America, formerly of Chicago, but now of Boston. Since the war their laboratories have been closed, but it is possible that these will be reopened when we finally make peace with Germany.

THERMOELECTRICITY AND THE CONDUCTIVITY OF METALS

The study of thermoelectricity seems preëminently to be fitted to reveal to us the real nature of the phenomena of heat and electricity. Of special interest is, therefore, the lecture recently delivered by Prof. Carl Benedicks, of the University of Stockholm, before the British Institute of Metals on the "Recent Progress in Thermoelectricity." His essential point was this: Metallic conduction is not to be ascribed to an "electron gas" filling up the space between the atoms, the metal acting as a cage for the electrons, but is due to the passing of electrons from atom to atom at the moments of the incessant collisions of the atoms which we assume, for other reasons, to occur even in solids. Without entering into much theoretical detail, Dr. Benedicks outlined his considerations and demonstrated the experiments which have led him to his "phoretic electron theory of metallic conductivity," which was stated as follows: If the electric charges be carried by the atoms and be not free, the increase in the kinetic energy of the atoms, and hence the heat generated must be equal to the work done and must be proportional to i^2, whether the atom in question preferentially assume a positive charge or a negative charge. That preference is not unimportant in other respects, however. Supposing an atom inclines to assume a positive charge e. Let it rebound between two atoms I and II, and let a potential difference V be established such that the positive current is from I to II. In position I the atom will assume a positive charge; owing to that charge it will be accelerated on rebounding until it reaches II and gives up its charge, to be reflected at now constant velocity. On colliding with I again, it is again accelerated, and so on. In this mechanism of conduction the average kinetic energy of the atom in position II must be greater than the average energy at I by a constant amount $eV/2$, and that signifies that the temperature in II must be higher than in I. Similarly it may be shown that for atoms inclining to assume a negative charge, the temperature would increase in the direction of the negative current. The former case would be that of platinum and of constantan, the latter—that of copper. Copper would be inclined to take up electrons, to associate them; platinum would be inclined to discard electrons—to dissociate them; lead, in which there seems practically to be no thermoelectric effect, would as readily associate as dissociate electrons.

It is evident that this theory is in contradiction to the law of Magnus, that in a homogeneous metal, whatever the temperature distribution, thermo-currents do not exist. To put the problem plainly, the question is broadly whether temperature difference and heat flow always go together with potential difference and electricity flow. In briefly reviewing the earlier investigations, Dr. Benedicks distinguished three periods: a first period, 1821 to 1838, of active somewhat uncritical experimenting; a second more critical period up to 1885 which finally accepted the law of Magnus, that no thermal current would occur in a really homogeneous metal, all apparent deviations being ascribed to impurities and to physical or chemical heterogeneity; and a third period, since 1898, which questions the law of Magnus. After five years of research Dr. Benedicks has arrived at the conclusion that this law cannot be maintained; he is its most eminent opponent and he demonstrated the reasons for his dissent. He performed many experiments, but he relies chiefly on the thermoelectric effect observed in mercury. Mercury is a liquid, as such free from internal stress, and obtainable in high purity; there it should be possible to decide whether the assumed Thomson effect is not after all merely a Peltier effect. Many experimenters have taken this latter view; but very careful experiments made with mercury in vessels of glass, or other materials, so constructed that hydrostatic-pressure stress could not arise, have convinced Dr. Benedicks that there is a thermoelectric effect in pure homogeneous mercury, and that it is of negative sign, as it should be. The effect is moreover proportional to the third power of the temperature, which is theoretically important, while it should be proportional to the first power in a heterogeneous circuit.

Having established that there is a homogeneous thermoelectric effect, Dr. Benedicks sought to determine whether there was inversely also a homogeneous electrothermic effect more

general than the Thomson effect, as one should expect if the analogy of the phenomena were complete. In the Peltier effect an electric current gives rise to a temperature difference and a heat transfer, even if the temperature be originally uniform throughout the circuit; in the Thomson effect, on the other hand, the electric current seemed to produce a temperature difference only when there was a temperature gradient from the beginning. By a long series of experiments on various metals and alloys, mercury, graphite, etc., Dr. Benedicks convinced himself that the analogy was complete. Thus two new (or formerly doubtful) Benedicks effects have been demonstrated; a thermoelectric and an electrothermic effect in a homogeneous circuit of one substance originally at uniform temperature throughout.—*Engineering*, Vol. 109, 1920.

PROF. W. H. ECCLES ON WIRELESS PROGRESS

PROFESSOR ECCLES recently delivered an address before the Wireless Section of the Institution of Electrical Engineers in which he reviewed some outstanding features of the wireless development.

In 1913 musical spark method of transmission was still in use at some of the largest stations of the world, with the arc, the timed spark and the various forms of alternator as formidable rivals. Signals from spark stations were received by crystal detectors, by Fleming valves or by audions with two electrodes and continuous wave signals by the ticker and the tone wheel. Continuous wave circuits did not show outstanding advantages over spark circuits, for the heterodyne method of reception was cumbersome in practice and lacked many of the features which have made modern methods so successful. During 1913, however, the possibility of generating oscillations of very high frequency was realized and the heterodyne method of reception then sprang on to a different plane. For the three-electrode vacuum-tube aerial not only magnifies the signals at the same time as it generates the oscillations, but is so simple, perfect and manageable that it realizes the highest ideals of the wireless engineer. Combined with its positive retroaction between the anode and grid circuit it still possesses the rectifying property of the Fleming valve. It was thus found possible to generate local oscillations, to magnify the received signals and to rectify the combined result all with one tube. This gave to continuous wave wireless telegraphy an immense impetus over the spark method for long-distance work.

Such was the situation in England at the beginning of the war. Of the progress made since the most important feature has been the development of the triode, which instrument is now in the same stage of development as the dynamo machine was 40 or 50 years ago. To develop it it must be studied to the limits of its possibilities, endless measurements must be taken, and its theory must be built up.

After discussing briefly the voltage factor and giving a curve with the values of the voltage factor as the ordinates and the voltages of the battery permanently connected in the grid circuit as abscissae (the filament current being constant), the author mentions some anomalies of the triode working. It is found that the voltage factor undergoes great variation when tubes are used for magnifying rather larger changes of voltages than are applied to them in the bulk of wireless telegraph experiments. This leads to apparent anomalies when triodes are used for other purposes than the reception of faint wireless signals. It is possible that the changes usually occurring in the wave-lengths generated as the filament battery runs down owe their origin to the variations in the average value of the voltage factor, but by using the flat part of the curve the filament currents may be set so that this alteration will for a long time produce no change in the wave-length. The constancy of wave-length will become of growing importance as the world becomes crowded with wireless stations, and methods of transmitting within very narrow ranges of wave-length may have to be devised in combination with receiving antenna and apparatus with sharp tuning. The increased cost of low resistance antenna and apparatus will have to be compared with a possible saving of energy and other advantages of precise tuning.

The author then gives a relation for the remaining four principal variables of the triode: the anode current, the grid current, the anode voltage and the grid voltage. Upon the axes representing the anode voltage, the grid voltage and the third grid or anode current the author constructs and gives illustrations of the characteristic surfaces of the triode. Finally, he discusses the problem of directive reception. The perfecting of high-power amplifiers has had the important result of making possible the directive reception of distant stations by small antenna. For instance, it has been possible to receive transatlantic signals in England with a small frame aerial a yard square and to determine its direction by rotating the frame about a vertical axis. False directions are, however, obtained during the sunrise and sunset periods, and it has been suggested that much of the directional error might arise from the rotation of the plane of polarization of the signal-bearing waves by reflection of the non-level portion of the heavy-side layer between the sending and receiving stations. It has, moreover, been abundantly proved that rays bending round the globe follow a curved trajectory resembling that of a projectile. In the daytime these magnetic rays have their force horizontal, but if at night the plane of polarization is rotated in any manner, the apparent direction of the source of radiation would become erroneous. The cause of the rotation of the plane of polarization is still a problem. It is evident that the earth's magnetic field will introduce obliquity into the motions of ions propelled by the electric force of the waves. Waves passing over any particular ion impart to it a to-and-fro motion of the same period as that of the waves, but lagging behind their electric force by about a quarter of a period. An ion moving in the earth magnetic field is deflected by that field and acquires an oblique component of velocity while a calculation shows that a rotation such as is demanded by the observed facts of directive wireless telegraphy might be furnished by the passage of waves through a space containing free electrons.

Further, the longer the wave the greater the directional error should be, and if a station transmits a group of slightly differing wave-lengths a kind of spectrum analysis could be performed by a radio-goniometer. The information gained from observations made with directive aerials must be combined with the knowledge furnished by an analysis of the records of magnetic variations and magnetic storms. It would seem that the diurnal variations of the range of wireless signals must be due to the kind of ionization of gases familiar in laboratory work with X-rays and the γ-rays from radium.—*Electrician* (London), December, 1920, pp. 678-680.

SOME RECENT GERMAN WELDING MACHINES

THE *Engineering Progress* for September, 1920, describes a *stepping* roller welding machine which works on the principle of resistance welding. The older types of seam welding machines used to work with uniformly turning welding rolls in such a manner that an alternating current of low pressure and high amperage was transformed in the machine in passing from one roller to the other through the path to be welded. The material to be welded was inserted between the two rollers. The resistance which is offered to the passage of the current at the surface of the contact of the two pieces of material to be welded together converts the electric current into heat. The material is brought up to welding temperature and is joined together by the pressure of the rollers. By the uniform rotation of the roller the seam passing between the two rollers is welded together in one uninterrupted operation. The working speed is comparatively high, yet this rapid process has not been introduced to any great extent: it was too sensitive even against slight impurities of the welding surfaces and small obstacles in the rotation of the rollers and for

this reason it has in fact never been possible to assure with this process a permanently satisfactory operation.

The stepping rollers process placed on the market by the Gesellschaft für Elektrotechnische Industrie in Berlin has remedied the above-mentioned faults. With this new process the welding rollers do not turn uniformly, but after a partial turning movement they are arrested for a moment in order to proceed with another partial turning movement. Such partial turning movements or steps are made by the roller at the rate of 10-800 per minute, varying according to the thickness of the material to be welded. At every partial rotation a distance of from 1/16 to ½ inch is covered by the roller, this distance varying with the thickness of the material. The welding current is coupled to the movement of the roller in such a manner that at the moment when the roller comes to rest, after having completed one step, the current is switched on. The part of the material below the roller at that time is heated up to welding temperature and is welded by the pressure resting upon it. Immediately afterward, the current is interrupted for a short period, the roller will keep up its pressure upon the welded part, until the latter has cooled down under the pressure and under exclusion of air to such an extent that sufficient strength is obtained to prevent the material from being torn apart by any tension in the material. This new process has shown excellent results; even sheet metal with very unclean surfaces covered with scale has been welded according to this process in a faultless and clean manner. The reliability of the operation of this new machine is claimed to be so great that it has become possible to design automatic seam welding machines on this principle up to any output. The wear of the electrodes is very small; even if the sheets are covered with scales the electrodes remain perfectly clean.

A number of electric welding machines built by the Moll Works of Chemnitz are described by T. Vaillant in *Elektrotechnische Zeitschrift* for August 19, 1920. The butt welding machine manufactured by this company contains a 75-kva. transformer with 5 step-down ratios. The ends of the pieces to be welded are clamped between cheeks that form at the same time the secondary terminals of the transformer. The cheeks are water-cooled, and can be moved toward each other during the process of welding, so as to press the welded surfaces together. The energy required for welding bars from 19 to 50 mm. in diameter ranges from .057 to 1.346 kw-hr., and the time required per weld varies for these sizes between 10.7 sec. and 143.2 sec. The water consumption is 86 liters per hour. The company also makes electric rivet heaters and machines for welding sheets and chain links.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

JUNKERS WATER EDDY BRAKE

DESCRIPTION of a water brake of the eddy type employed in the testing laboratory of Doctor Junkers for testing oil engines with a power output of the order of 1,000 horsepower. Essentially, the brake consists of the rotor A (Fig. 1) keyed on a shaft and a stator B located centrally to the shaft. The stator and rotor are provided along their periphery with finger-like attachments arranged in a certain manner, water being circulated between these attachments. If now the rotor A be set up in rotation the water between the finger-like attachments offers a resistance which converts the energy supplied by the motor into heat and this heat is in its turn

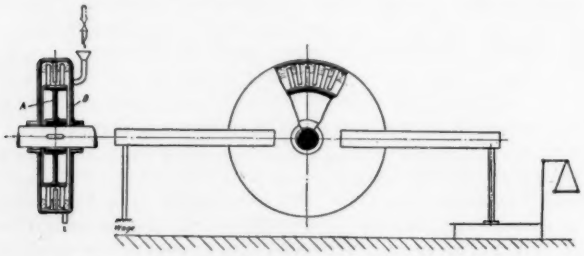


FIG. 1. JUNKERS WATER BRAKE, EDDY TYPE

carried away by the water. The brake has, therefore, no solid parts rubbing against each other. The thickness of the water rings determines the output which the brake is capable of handling and the regulation of the brake is carried out in a very simple manner by varying the level of the water rings which is done by regulating the water inlet and outlet valves. Preferably, water admission is so regulated that no steam is produced as this would make conditions in the test room unpleasant.

If water is admitted at 10 deg. cent. (50 deg. fahr.) and let out with an outlet temperature of 65 deg. cent. (149 deg. fahr.) then the brake needs 636 = 11.6 kg. of water per b. hp-hr. The brake is equally suitable for all kinds of motors, outputs and speeds. Thus the original article illustrates a brake of this type applied to the testing of an exhausting turbine of 6,400 hp. at 210 revolutions. Another illustration shows a 600-hp. Diesel motor, etc. One of the advantages claimed for this brake is that it prevents the engine from running away under any conditions whatsoever.—*Wirtshafts-Motor*, No. 9, Sept., 1920, pp. 19-20.

POWER AND FUEL FACTS

THE following figures are of great interest:

Prime movers of all kinds in U. S. (Stationary and locomotive)	100,000,000 hp.
Used at average load factor of	14 per cent
Used for average period per week	23.5 hr.
Develop per year	125 billion hp. hr.
Water power available	50,000,000 hp.
Coal (without lignite), in ground	2,500 billion tons
Petroleum, in ground	7 billion bbl.
Used for power only (locomotive and stationary) on basis of present power delivered, resources will last:	
Water power, if all developed	indefinitely
Coal used by best practice	57,000 yr.
Coal used by average practice	7,500 yr.
Petroleum (allowing 40 per cent gasoline)	9.25 yr.
Of prime movers installed:	
Steam plants, coal fired make up	8.2 per cent
Hydraulic plants, make up	8.2 per cent
Combustion engines and other types, make up	39.8 per cent
Of power developed:	
Public utilities use	42 per cent
Manufacturing plants use	28 per cent
Railroads use	30 per cent
Of 1 ton of coal in the ground	2,000 lb.
Best recovery brings to the surface	1,900 lb.
Average recovery brings to the surface	1,400 lb.
Poor recovery brings to the surface	1,000 lb.

Power to operate the coal mine takes	100 lb.
Turned into useful work at point of application:	
By best large central stations	608 lb.
By best small central station	304 lb.
By locomotices best practice	175 lb.
By small individual plants, average practice	76 lb.

Power Plant Engineering, Vol. 25, No. 1, Jan. 1, 1921.

POSSIBLE FUEL SAVINGS IN AUTOMOTIVE ENGINES

H. C. DICKINSON AND S. W. SPARROW

REPORT of tests carried out at the Bureau of Standards. The apparatus employed permitted of seeing the acceleration of the engine by means of an acceleration disk mounted on the dynamometer shaft. This was of steel 33 in. in diameter and ½ inch thick. Its inertia added to that of the dynamometer was about equal to that of a 3,500 lb. car on direct drive with a gear ratio of 5 to 1 and 32-in. wheels.

Among other things, the tests covered the influence of jacket water temperature on fuel economy. Two series of tests were

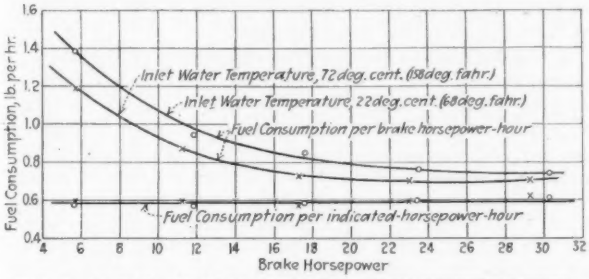

Fuel Consumption, lb. per hr.
Brake Horsepower
Inlet Water Temperature, 72 deg. cent. (68 deg. fahr.)
Inlet Water Temperature, 22 deg. cent. (68 deg. fahr.)
Fuel Consumption per brake horsepower-hour
Fuel Consumption per indicated-horsepower-hour

FIG. 2. CURVES SHOWING THE RELATION BETWEEN FUEL CONSUMPTION AND JACKET WATER TEMPERATURE

made; in the one the temperature of the water entering the jacket was maintained at 162 deg. fahr., and in the second at 72 deg. fahr. Runs were made at full load 0.8, 0.6, 0.4, and 0.2 of full load, with five carburetor adjustments at each throttle setting. From these results the minimum fuel consumption for each setting has been selected and plotted in Fig. 2. From this it appears that the fuel consumption per unit power based on brake horsepower is considerably higher with the cold jacket water.

It may be mentioned in this connection that tests made several years ago by J. B. Replogle have shown that a very considerable economy in fuel consumption is obtained when the temperature of water s carried to a still higher point than was used by the Bureau of Standards in its test, namely, at the boiling point.

Other tests cover the influence of intake manifold heating on acceleration and on the maximum horsepower of the engine, it having been found that heat supplied to the charge increases the maximum power of the engine.—Paper presented at the meeting of the American Petroleum Institute, Nov. 17, 1920, abstracted through *Journal of the Society of Automotive Engineers*, Vol. 8, No. 1, January, 1921, pp. 3-9.

RECORDING SPEED INDICATORS

BY A. G. NEWELL

WHILE the recording speed indicator might be of great service in railroad operation, as the author points out, there are many elements some of which are of psychological rather than mechanical character which have so far interfered with its useful adoption. Some operating officials are rather reluctant to set a speed restriction and require its observance at all times. Engineers who are not familiar with the working of the speed recorder are also apt to look upon it with disfavor, even though they often change their opinion after becoming familiar with it, as they realize that an instrument of this kind eliminates taking of chances by the other fellow and puts each crew on the same basis.

A speed recording device on the locomotive is of particular interest as it permits more certain and curiously enough more rapid operation over bridges in bad condition, slow track or curves. At present it is the practice of a good many foremen to place very slow limits of speed over bridges and parts of track undergoing repairs, in the expectation that enginemen would not hold their trains to the letter of the order and would, in most cases, make two or three times the speed that the order called for, with the result that enginemen obedient to the order go at speeds very much lower than is actually necessary. The correct speed can be set and maintained, however, without difficulty where recording speed indicators are used.

The experience of the El Paso and Southwestern System is described in practice. Their experiments were started in 1907 with a Flaman tachograph brought from France. This instrument gave satisfaction and in 1911 three more of the same make were applied. These four instruments met with such success that it was decided to adopt them as a standard appliance for all road engines on the system. A mechanic was sent to the factory in France and made a thorough study of the instrument. A modern shop for testing and repairing was then fitted up at the General Shops at El Paso, Texas. Since then 114 locomotives in road service have been equipped with the Flaman tachograph and there are sixteen reserve instruments on hand.

The apparatus has a speed indicating dial graduated from zero to 90, each division representing one mile in speed. A small black pointer plays over the face of the dial indicating the speed being made at all times when the engine is moving in either direction. The lower part of the case contains the speed and time recording mechanism and the recording tape, the record on the tape being made by two styles. A sample of a record is given in Fig. 3. The time recording style rises from the bottom line to the top line in a given interval, which, in various types of indicators may be either 10 or 30 min., making a sudden and vertical drop from top to bottom. The degree of inclination of the oblique lines made by the style depends on the speed being made, the greater the speed the less the inclination. During the time the engine is standing the time recording style will move up in a vertical line or a series of vertical lines, each full line from bottom to top rep-

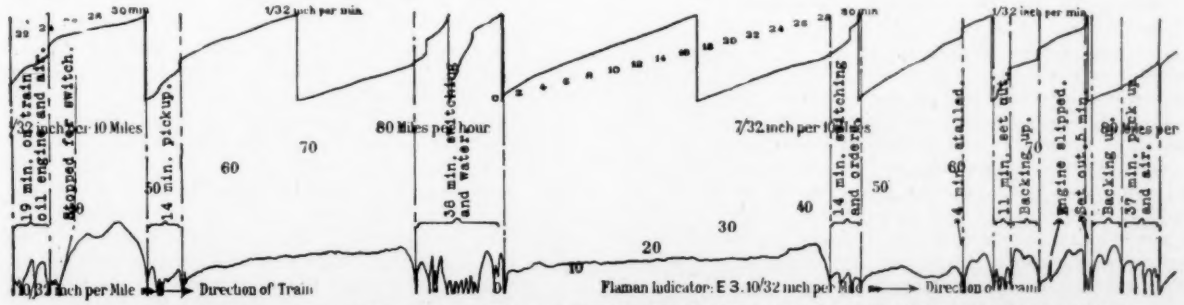


FIG. 3. SAMPLE OF TAPE MADE BY A FLAMAN TACHOGRAPH IN USE ON A LOCOMOTIVE OF THE EL PASO AND SOUTHWESTERN SYSTEM

resenting 10 or 30 minutes, depending on the tape used, and each fraction of a line its portion of time.

The mechanism of the instrument is of clockwork type and receives its motion from a series of springs which must be wound by the engineer by means of a small crank before the engine leaves the roundhouse track or at any time after the engine has stood for a period of 30 minutes or more during the trip. When the engine is moving in either direction the clockwork is wound automatically by means of transmission rods and gears, receiving its motion from a driving stud and arm attached to the right back side rod pin and will continue to run for a period of from 30 to 40 minutes after the engine has stopped.

The instrument is so arranged that tampering with it is quite difficult. The cost of the apparatus at present is said to be $270 for each instrument and $193 for applying it. The average length of time an instrument will stay in service without repairs is about four months.—*Railway Review*, Vol. 68, No. 1, Jan. 1, 1921, pp. 7-10.

REPORT ON TIDAL POWER OF THE WATER POWER RESOURCES COMMITTEE OF THE BRITISH BOARD OF TRADE

THE third interim report is particularly concerned with the question of development of tidal power in the Severn estuary.

The committee states that the importance of the project from the national standpoint cannot be easily overrated in view of the magnitude of the power involved and of the far-reaching character of the economic consequences which would follow the actual development of such a scheme if it could be carried out on sound economic lines.

From data presented one particular site on the Severn, not necessarily the best, might be rendered capable of developing tidal power representing a saving of from one and a quarter million to two and a half million tons of coal per year.

The question is to what extent can this be actually accomplished. In the Severn estuary the tidal amplitude is large, the configuration of the estuary is well suited to the purpose in view. The physical characteristics of the land in the vicinity are such as to facilitate the construction of a high level storage reservoir, while the adjoining industrial district is one in which the power requirements are already large and the power supply is likely to be absorbed completely for industrial purposes.

In view of this fact, the subcommittee composed of Sir Philip Dawson and Prof. A. H. Gibson was appointed for the purpose of a preliminary examination of the subject. While this subcommittee has not been able to secure any definite statement of opinion from the leading manufacturers of water turbines and electric generators and in a position to recommend the Severn scheme as a practical undertaking, its members came to the unanimous agreement that it certainly cannot be dismissed as impractical and that the further and more detailed technical inquiry into the subject of tidal power is amply justified and should be initiated without delay.

It is therefore proposed to appoint a larger committee for a more careful study of the problem and an intensive program of investigation for this committee is proposed.

What appears to be one of the greatest difficulties in the way of tidal power development is due to the intermittent character of the service which such a development can give. The report comes, therefore, to the conclusion that if an electrochemical, electrothermal or other process were devised capable of absorbing an intermittent power supply subject to such variations as are inherent in tidal power generation, the commercial value of tidal power would be greatly increased. Otherwise it would be necessary to provide means for providing the intermittent output into a continuous supply more or less constant throughout the working period and such conversion can be accomplished only at the expense of overall efficiency.—Abstracted through *The Engineer*, Vol. 130, No. 3390, Dec. 17, 1920, pp. 614-615.

AN EXPERIMENT WITH REST PAUSES

By J. LOVEDAY

PART of a report of the Industrial Fatigue Research Board. While the experiment covered a period of little more than six months, it is of considerable interest. The experiment was carried out at the plant of a firm having two factories, in one of which shoes were manufactured and in the other heels and stiffeners only.

In the stiffener and heel works all the employees with the exception of the foremen were women, the working hours in 1918 being 46 per week. In 1918 the firm found itself confronted with the problem of increasing output without adding new machinery, owing to the extreme difficulty of obtaining machinery at that time. The difficulty arose particularly in the press-room where the leather is cut into pieces of the shape required by a mechanical press working upon a heavy knife of the requisite form. The presses are of two types, single and double, a double press being a bench with a press at either end. The operation demands skill and care, flaws in the leather must be avoided, and the skin cut with as little waste as possible. The problem has been successfully solved by the adoption of the following plan:

It was determined to make the experiment of working the double pressed with a team of three girls, each operative working 40 minutes in each hour and resting 20 minutes, instead of with two girls working continuously throughout the day. It was hoped thus to increase the output of the machine, and how fully this hope has been justified by results will be seen from the figures below. The experiment was begun in January, 1919, on a machine with results so favorable that in July six double presses were being operated on this system. A comfortable and attractively furnished rest room, quiet and restful in color, has been provided, and but for the difficulty of arranging for further rest rooms, a difficulty which can only be overcome by building, the plan would already have been greatly extended. There the girls, when they come down from work, are free to rest or to occupy themselves with crochet, knitting, etc., as they may desire.

Six girls, one for each machine, go to the rest room on arrival at the factory in the morning, and do not start work until 8 o'clock: from then onward the period of rest is 20 minutes in the hour throughout the day. Those whose turn it is to rest at 11:40 a. m., and at the corresponding period in the evening, are allowed to go home. The experiment was constituted with the consent of the operatives after thorough explanation, and, though somewhat skeptical at first as to success, they were willing to give it a trial.

The operatives are paid by day rate plus a bonus on output. This bonus is computed by calculating the weekly output of the press and dividing it into three equal parts, so that the three members of each team receive an equal bonus, proportional to the amount of work done during the week.

With the new arrangement a total increase of output on the six presses was obtained amounting to over 44 per cent and this very high figure is attained with the reduction of the working hours of the individual operatives by one-third, and without the addition of new machines. Sufficient data are not available to draw any accurate conclusions as to the actual increase or decrease in output of individual workers, but it would appear that there was such an increase. In particular, it appears that a change benefited specially the comparatively unskilled and the less robust workers.

As regards the effect on workers, it is stated that at first the girls did not believe the scheme would prove successful, and did not believe they could put out enough in such short hours. Experience, however, reconciled them to the system and none of them at the time of the investigation desired to return to the former hours. This was particularly so in the case of the weaker and less highly skilled girls.—*Report No. 10 of the Industrial Fatigue Research Board*, (Great Britain), abstracted through *Engineering and Industrial Management*, Vol. 4 (New Series), No. 23, Dec. 2, 1920, pp. 716-718.

Progress in Mining and Metallurgy

Abstracts of Papers and Recent Articles

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

DUST-VENTILATION STUDIES IN METAL MINES

By D. Harrington

Investigations in mines of foreign countries, as well as of the United States, prove that breathing air containing minutely divided dusts is likely to be harmful to the health. The most harmful dust is apparently that which is practically insoluble and breaks into minute particles with sharp, cutting edges. Free silica, such as quartz, flint, etc., has these harmful properties to a great degree and is thought to be the most harmful of dusts. Silicates are also insoluble and some of them break into fine particles with cutting edges, but they do not appear to be as harmful as quartz. The harmful dust, in general, is smaller than 10 microns, or about 1/2500 in. Inasmuch as probably much over 50 per cent of all metal mining in the United States is in siliceous material, the importance of the dust problem is manifest.

While fine siliceous dust is likely to be dangerous, especially when the dust is free, such as quartz, a mine working in quartz material may have especially dusty conditions and the employees be apparently immune to diseases of the respiratory tract.

1. The quartz may be in a condition of partial alteration, due, to heat, pressure, or chemical solutions, and bear somewhat the same relationship to unaltered quartz, as to sharpness and hardness, as would decayed oak to the original dry hard material.

2. The quartz dust may be associated with some other dust so that the harmful features of quartz dust (sharpness and insolubility) are neutralized or eliminated. The latter is essentially the adsorption theory advanced by Haldane.

3. A mine having dry siliceous material drilled dry, even using a large percentage of upper holes and hence producing the maximum amount of fine dust, may be comparatively harmless to the health of workers if sufficient air currents are provided to sweep the dust away as it is formed, the workers keeping as much as possible to the fresh-air side of the drill. In general, compressed-air blowers (supplying about 100 cu. ft. of air per min.) are inadequate to ventilate these dusty places properly so definite means, such as small fans and tubing, must be provided to cause a current of 1,000 or more cu. ft. (28 cu. m.) per min. to pass the worker and either take away the dangerous fine dust from the working place or reduce the dust content of the air at the working place below the danger point.

While siliceous dust is probably the most harmful, it is the opinion of the writer that all dusts, especially those insoluble in water (and some that are soluble) are likely to be ultimately harmful to the health of breathers; this applies to coal dust as well as to strictly mineral dusts.

The writer cannot concur in the recently advocated policy of introducing foreign dusts to neutralize dusts known to be dangerous to health. In metal mines, dust must be removed or its formation prevented. The introduction into coal mines of suitably chosen stone dust to prevent explosions is commendable because of the immensely greater menace of explosions than of any probable health feature in rock dust, provided the latter is carefully selected.

The dust menace in metal mines is at its worst:

1. To workers in comparatively dry places in siliceous ore in dry drilling of upper holes in unventilated places, especially if the air is above 80° F. (27° C.) and 85 per cent relative humidity.

2. To workers in comparatively cool dry places where air is not kept moving by ventilation.

3. To workers in dry mines, or places, where blasting is done while men are on shift.

The principal measures for the prevention or removal of dust in metal mines are as follows:

1. Eliminate dry drilling.

2. As far as possible, blasting when men are on shift should be avoided.

3. Dusty places, such as manways, chutes, loading or dumping places, downcast haulage shafts, etc., should be kept damp by permanent water sprays.

4. The introduction of large quantities of water by the use of wet drills, sprinkling, etc., will cause the underground air to be practically saturated with moisture, a condition generally held to be harmful.

5. Where formation of dust cannot be prevented, one of the most efficient methods of removal is to sweep the dust-producing places with 1,000, or more, cu. ft. of air per min.—To be presented at the New York Meeting of the Amer. Inst. of Min. and Met. Eng., Feb., 1921.

THE HEALTH OF THE UNDERGROUND WORKER

By A. J. Lanza

Industrial medicine bids fair to become one of the most important and highly developed branches of medical science. Mining companies, even in remote district, have developed large and efficient medical organizations that comprise the best types of physicians and surgeons.

The mine doctor who never goes underground must remain ignorant of the factors causing many of the disorders he treats as well as miss the best opportunity of gaining the respect and coöperation of the men he serves.

It is impossible to define the exact organization of a medical service for a mining community or company. Local conditions vary greatly, as does the responsibility of the company to its employees. If the doctor and the company are imbued with the idea that high-grade surgical and medical service is possible, desirable, and profitable and if the doctor will endeavor to apply the principles of scientific medicine, including prevention as well as cure, any type of medical organization suitable to the local needs will be a success. Where these ideals are not recognized, the most elaborate medical machinery will not give satisfactory results.

In mining, rescue and first aid work have been developed to a higher point than in probably any other industry.

The men should be urged and encouraged to go to the company dispensary or hospital for minor ailments, such as coughs, colds, and the like.

Industrial workers, especially foreigners, often will not call in a physician until sever illness compels them.

A visiting nurse, or nurses, is a valuable adjunct to any medical service. Such a nurse will call on men absent on account of sickness, see that the sick are properly cared for, help the family in time of stress, and be a potent factor in promoting public-health work. Tact and discretion are absolutely necessary for a visiting nurse, who should be responsible to the doctor and should not be diverted from her proper function.

It would be absurd for industry to take the stand that only those can work who are able to pass a fairly rigid physical examination, but it is fair to assume that no man has a right to work at a specific occupation where, as a result of his physical condition, he might be a source of danger to himself, his employers, or his fellow employees. The physical examination makes it possible to recognize and record physical defects

and thus prevent their being charged against the company in the event of an accident. Certain employees such as hoisting engineers, cage tenders, rescue men, fire crews, shot firers, and men working on underground haulage systems should be examined not only when hired but at stated periods.

The successful conservation of the miner's health depends on three basic principles: He must be physically adapted to his work, he must be guarded from undue hazard while at his work, and he must receive skilled and prompt attention when injured or ill.—To be presented at the New York Meeting Feb., 1921.

THE FUEL SUPPLY OF THE WORLD

By L. P. Breckenridge

At the Annual meeting of the American Society of Mechanical Engineers, in December, 1920, the sessions devoted to fuel and its conservation aroused great interest. Among the papers presented was one by Mr. Breckenridge on the fuel supply of the world, from which we have excerpted the following paragraphs, reprinted from the January number of *Mechanical Engineering*:

HOW TO PREVENT WASTE OF COAL

1. Extend as rapidly as possible improved methods of mining coal. At present one-third the bituminous and one-half the anthracite coal is left in the mine under such conditions that recovery is practically impossible.

2. Extend improved methods of "preparation" of coal at the mines. A premium might well be allowed for well-prepared coal, or a penalty imposed for impure coal.

3. Reduce the hazards of coal mining. For every 1,000,000 tons of coal mined there are between four and five fatalities.

4. Operate the mines a maximum number of days each year. Mines are operated from 200 to 240 days in one year. Lost time is due to three principal causes: shortage of cars, shortage of labor or strikes, and mine disability.

5. Utilize a larger amount of the mine waste. Briqueted fuel, pulverized fuel and electricity from mine waste are all possible of successful development.

6. Increase the use of byproduct coke ovens. The byproducts wasted by beehive coking are equal to fully 600 lb. of coal per ton of coke produced. Increase the use of domestic coke from the local gas plant.

7. Extend the use of blast-furnace gas for power generation. Much progress has recently been made. It will require coöperative effort to utilize fully the power which might be made from blast-furnace gas.

8. Extend the use of the gas producer, the gas engine and the heavy-oil engine for power generation, more especially where electrical energy is not available. Develop the lignite fields—by power from gas producers—and briqueted fuel for domestic use.

9. Extend waterpower development. Hydroelectric power often combined with steam power offers large possibilities for saving coal. It will require comprehensive expert study before any new development can be undertaken, or satisfactory financial returns may not be possible.

10. Extend very generally the best-known performance of locomotives. The better locomotives of 1920 use only two-thirds of the coal required 20 years ago to do the same work. Much saving should be expected in the operation of steam locomotives. Electrification will save coal where water power is conveniently available. Instructions to firemen should be given and followed up even more carefully than in the past.

11. Encourage the tendency of the small industrial plant to purchase its power. The best coal is often sent to the small plant. Small plants like individuals should be examined by experts and all reasonable effort made to conserve fuel. Correct equipment and correct methods of operation would save 20 to 25 per cent of the coal used in industrial plants. It is the coal saved by the industries that will set free transportation facilities sorely needed for other purposes than hauling coal. One-third of the railroad tonnage of this country is coal.

12. Furnish homes and public buildings with correct and simple instructions for operating the furnace, heating, boiler and stove. This involves using fuel with suitable equipment for burning it. This should result in saving from 10 to 15 per cent of the domestic coal consumed.

Table 1.—*Total Coal Reserve of the World in Millions of Tons*

X. INTERNATIONAL GEOLOGICAL CONGRESS, CANADA, 1913

EASTERN HEMISPHERE

Europe		Africa	
Germany	423,356	South Africa	56,200
Great Britain and Ireland	189,533	All others	1,639
Russia (in Europe)	60,106		
Austria	53,876		
France	17,583		
Belgium	11,000		
All others	28,736		
Total for Europe	784,190	Total for Africa	57,839
Asia		Oceania	
China	995,587	Australia	165,572
Siberia	173,879	New Zealand	3,386
India	79,001	All other Islands	1,452
Indo-China	20,002		
Japan	7,970		
All others	3,147		
Total for Asia	1,279,586	Total for Oceania	170,410
Total for Eastern Hemisphere	2,292,025		

WESTERN HEMISPHERE

North America		South America	
United States	3,838,657	Colombia	27,000
Canada	1,234,269	Chili	3,048
All others (including Central America)	505	Peru	2,039
		All others	10
Total for North America	5,073,431	Total for South America	32,097
Total for Western Hemisphere	5,105,528		
Total reserve for the world	7,397,553		

Table 2.—*Annual Production of Coal in the United States*

	Millions of Short Tons			Millions of Short Tons	
Year	Anthracite	Bituminous	Year	Anthracite	Bituminous
1880	30	44	1915	86	435
1890	42	110	1916	87	460
1900	60	210	1917	88	500
1905	70	310	1918	87	566
1910	82	420	1919	86	420
1914	84	420	1920	84	(510)?

Table 3.—*One Year's Fuel Requirements of the United States and Their Coal Equivalent* (13,000 B.t.u.)

Kind of Fuel	One Year's Fuel Consumption	Approx. Coal Equivalent (Tons-2,000 Lb.)	Conversion Factors
(1) Peat	25 thousand tons	12,500	2 tons = 1 ton coal
(2) Natural gas	800 billion cu. ft.	27,000,000	30,000 cu. ft. = 1 ton coal
(3) Wood	80 million cords	40,000,000	2 cords = 1 ton coal
(4) Water power	7.5 million developed water horsepower	55,000,000	33 per cent load factor 5 lb. coal per hp.
(5) Petroleum	360 million barrels	100,000,000	3.6 bbl. = 1 ton coal
(6) Coal	650 million tons	650,000,000	
Total		872,012,500	

13. Extend the custom of coal storage. The facts relating

to this important practice are now available. Coal may be safely stored and the load curve on the mining industry may be much improved. The coal should be stored at or near its point of consumption.

14. Extend electrification. The full use of electrical energy offers the most promising means of saving coal. Conservation by coöperation of water power, steam power and electricity opens up large possibilities for saving coal, capital and labor. This is contemplated by the superpower plan now being investigated by the Department of the Interior and a report is in preparation by an engineering staff which will set forth the facts as to: (*a*) Needs for superpower, (*b*) characteristics of an installation, (*c*) location of suitable superpower lines, (*d*) estimated costs, (*e*) estimated economies and other details.

Correspondence

The editor is not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.

THE CENTER OF THE EARTH

To the Editor of the SCIENTIFIC AMERICAN MONTHLY:

May I venture to add to your "center of our earth" discussions? We assume that the center of the earth is at great temperature and compressed to great density. This mass comprises all but a less than orange peel proportion of crust. As the center cools it contracts, as the exterior disintegrates it expands. Both actions make the crust a poor fit. That it crumples and folds is evidenced in the strata of mountain ranges and coast lines. As it crumples there is a local shifting to a new equilibrium, with its accompanying quake or quakes, just as ice moves in a glacier, readjusting pressures by regelation, so the unaccommodated masses of the earth's interior, as the pressure increases, will liquefy and burrow to a position of readjusted pressure, leaving their traces in dikes, pipes, laccoliths, in case they do not reach the surface. In case the regelated magma reaches the surface it is a question of the heat and pressure still retained as to whether it is an explosive or a more or less quiet flowing lava stream. If the contained energy of heat and pressure is sufficient there is no reason whatever why the mass itself should not spring into the vapor of its own constituents later to be sublimated into the powder which circled the globe after Krokatoa or that buried Pompeii and Katmai. The drive of exploding water is not necessary to volcanic action.

New York. GEORGE N. COLE.

"IS THE EARTH EXPANDING OR CONTRACTING?"

To the Editor of the SCIENTIFIC AMERICAN MONTHLY:

There appeared in the July issue of the SCIENTIFIC AMERICAN MONTHLY, an article by Hiram W. Hixon, entitled "Is the Earth Expanding or Contracting?" It was accompanied by a letter by the same author criticising an article on "The Ballistics of Volcanoes," by M. Belot, which had appeared some time previous.

I wish to take issue with Mr. Hixon in many of his statements. Much of his evidence could equally well be used to support theories contrary to his own; and he overlooks evidence which can only be read contrary to his theory.

Speaking of the elevation of lands and of mountain ranges above the sea, he says, "The contraction hypothesis is incompetent to explain these changes of altitude because of lack of strength in the crust. . ." He tacitly assumes that in order to form elevations and depressions by contraction of the interior, the crust would at the elevated areas, have to stand by its own strength, *entirely* without support. In other words, he tactily assumes a *solid* contracting core, altogether separate from a solid crust. This solid, non-conforming interior which he evidently has in mind is the direct contrary of the fluid interior which he postulates in other places in his article. Both cannot concurrently be true. If the fluid interior be postulated, then that very lack of strength in the crust which he mentions would cause partial collapse of the crust until the fluid had been forced up to support the higher parts of the crust sufficiently to maintain equilibrium. If the crust had greater strength, we would expect fewer irregularities.

In his statement that the great predominance of "expansion faults" over "compression faults," proves that the earth is expanding, he fails to take all of the data into consideration. He does not take into account the fact that the earth may be contracting while its crust is expanding to take care of the greater roughness of the surface. He also fails to take into account the fact that even if the earth were contracting much faster than it is, still the "expansion type" of fault would be the normal, by reason of the fact that the co-efficient of friction of rock against rock is greater than unity; and unless the angle of fault with the plane of compressive forces, were very small, bodily crushing of the rock would take place before faulting through compression only. In other words, the predominance of normal faults proves nothing.

Mr. Hixon assumes that the earth was in the beginning a mass of incandescent gas; that the gas cooled superficially and solidified directly forming a crust.

It has been demonstrated in our laboratories that our common gases have average molecular velocities approaching the velocity of escape from the earth at the earth's surface. Individual molecules probably frequently exceed that velocity and would escape, were their paths not obstructed by slowly moving molecules. If the whole earth, including the crust, were gaseous, the diameter of the mass would be some thousands of miles greater than it now is, with a resultant very much diminished velocity of escape at the surface of the mass. Mr. Hixon's assumption of incandescence also involves much greater molecular velocities than those which hold at ordinary temperatures.

The combined result of these two conditions would be a very rapid dissipation of the gas at the exterior of the mass into space. This tendency would be enhanced as the central mass became smaller through loss of the dissipated gas, by a correspondingly weakened central gravitation. And while it is also true that reduction of pressure and consequent expansion and cooling of the interior gases would have some counteracting influence, this influence would not be sufficient to hinder dissipation since molecular velocities decrease only proportionately to the square root of the pressure or temperature.

And even assuming that parts of the gas did come into proper conditions for liquefaction or solidification, and that this took place, the solidified particles would immediately by their greater density fall down into the hotter mass below where they would be re-volatilized, and their place on the surface taken by more hot gas from below. The net result of this would be a state akin to ebullition which would keep the temperature uniformly distributed and help further dissipation. Indeed, we would expect storms of a thousand times greater intensity than we have in the earth today, and which would rival the sun's storms in violence. It is, of course, unreasonable to suppose that the whole crust solidified instantly and was thus prevented from falling into the central gas by its own structural strength as a dome.

I have not space to go into it further here, but believe I have made it sufficiently evident that a body of incandescent gas of the order of mass of the earth would not be stable, but would dissipate into space. And we can only conclude that, whatever its original condition, the earth was not originally incandescent gas.

I will say in passing that a body of gas of much larger mass than that of the earth would have a relatively much

greater centralizing influence and would not dissipate. The proof is too lengthy to give here, but I believe that anyone who has the requisite data and will go into it will be readily convinced that such is the case. Such a mass is the sun.

Now as to Mr. Hixon's hypothesis that the interior of the earth is gaseous and is expanding on solidifying:

I take from *Young's General Astronomy*:

	Mass	*Density*
Earth	1.0	5.55
Jupiter	317.7	1.32
Saturn	94.8	0.72
Sun	332,000	1.39

It will be noted that the earth has the smallest mass of the bodies listed, but the greatest density. Yet we know that the earth has the same general composition, at least, as the sun.

Were the earth and the sun both gas, the sun would have the greater density. Hence we are forced to the conclusion that both are in the main solid, or that the earth is solid and the sun gaseous. I purposely neglect to take into account the earth's crust as of relatively too small amount to influence this comparison. I believe that it is pretty plain that the hypothesis of a gaseous earth either past or present is untenable.

I will say that my own theory is that the sun and all planets are centrally solid; and that the low average density in those bodies of greater mass is explained simply by the fact that their great masses are able to hold a relatively much deeper atmosphere, which renders their apparent diameters much greater and correspondingly reduces the apparent mean density. This theory explains many facts not otherwise explainable. And if I am asked what becomes of the law of critical temperatures, I will say that either interior temperatures of the heavenly bodies are lower than they are supposed to be, or that the law of critical temperatures breaks down under the terrific pressures involved. Either assumption would be justifiable in the absence of direct experimental proof. Van der Waals' equation holds true only up to certain limits within experiment.

Mr. Hixson's criticism of Chamberlain's planetesimal postulate on the ground that the moon's craters show that the moon has once been molten, lacks connection.

We should certainly expect under Chamberlain's postulate that the moon at one time was molten—superficially at least. The heat of bombardment of planetesimal matter would be more than sufficient to account for that molten condition. In other words, a past molten condition of the surface of the moon neither proves nor disproves Chamberlain's postulate.

How does Mr. Hixon's theory account for a molten moon coexistent with an earth which he postulates passed directly from the gaseous to the solid condition?

Regarding the process of forming a solid crust, he tells us that as the mass of the outer surface falls below the critical temperatures of some of its constituents, they pass directly from the gaseous to the solid condition because gravitational compression has *raised the fusing point to the critical temperature.*

He has made here the double assumption: 1. That the cooled gases are on the outer surface of the gaseous core, and 2. That they are under gravitational compression sufficient to raise the fusing point to the critical temperature. Now fusing points rise very slowly under pressure. To be under sufficient pressure to have its fusing point raised to the degree he supposes would require that the gas be well down toward the center of the mass, below the cooling zone. This is contrary to his first assumption that it is on the surface. In other words, this direct passage from gaseous to solid condition is impossible so far as the ordinary substances of the earth's crust are concerned.

In his computations of the amount of lava required to furnish heat for volcanoes, geysers, etc., Mr. Hixon again neglects to take all possibilities into consideration. His arbitrary assumption of a cooling range of 750° seems very low. He fails to consider the possibility that radio activity or chemical action may produce heat. It is well known that many hot springs contain helium, a by-product of radio activity. The hot springs of Colorado are near known mines of radio-active metals. There are hundreds of chemical reactions which may be taking place deep underground which may be evolving heat in inconceivable quantities. Indeed, as most volcanic disturbances are near the sea coast, it is possible that the salts of sea water may be a catalytic agent, forwarding some of these reactions. There is an unlimited number of possibilities.

He says further: "As a result of rock flowage without melting, all cavities are closed at a depth of a mile or less. . . ." I see no warrant for this assertion. A temperature of 170° F., which is above that reached at a mile in depth, is not sufficient to reduce the rigidity of ordinary rocks sufficiently to permit flowing, even under the 7,000 pounds per sq. in. pressure which that depth entails. Building stones have been tested without failure to more than twice that pressure at ordinary temperatures. The refractories and other substances which are frequently stressed while under heat and are closely allied to the rocks in composition and structure do not begin to lose their rigidity until much higher temperatures than 170° Fahr. are reached. Is it then reasonable to suppose that the rocks would do so? Or if Mr. Hixon's assumption is correct, why have not the walls of the Grand Canyon, which is more than a mile and a half deep, flowed together and closed the canyon?

It has been authoritatively estimated that rock flowage does not take place until a depth of ten to twelve miles is reached. Until we have evidence to the contrary we may safely assume that cavities can exist, and surface water can penetrate to that depth.

Regarding his remark on the unreasonableness of steam generated *at sea level* forcing lava through a cone 4,000 ft. high,—I would call his attention to the fact that all theories of volcanic action assume that the steam is generated at a considerable *depth below sea level.* My idea of what very likely happens is that steam generated at a considerable depth first bursts through a weak point in the crust, forming a cone of ejected matter, and leaving a more or less open tube which serves as an easy vent for future activity. After that, the action is a good deal like that of the common air lift pump, which blows water to great heights above a source of supply by the simple expedient of introducing compressed air at the bottom of a pipe, one end of which is submerged.

There are a number of other points in Mr. Hixon's article which I might equally well criticise, but I believe I have said enough to show that his theory will not stand the test of reason in the light of known facts; and that M. Belot's hypothesis, supported as it is by experiment, has much the greater weight of probability with it.

New York, N. Y. LEO G. HALL.

"THE PATH OF A SHELL"

IN the December issue of the SCIENTIFIC AMERICAN MONTHLY we published an article by Waldemar Noll entitled "The Path of a Shell." A more technical article on the same subject and by the same author appeared in the *Monthly Weather Review* of December, 1919, page 868. To illustrate our article we reproduced a diagram appearing in the *Monthly Weather Review.* We regret to state through an oversight on our part, we failed to state the source of the diagram and acknowledge our indebtedness to the *Monthly Weather Review* for the use of the illustration.

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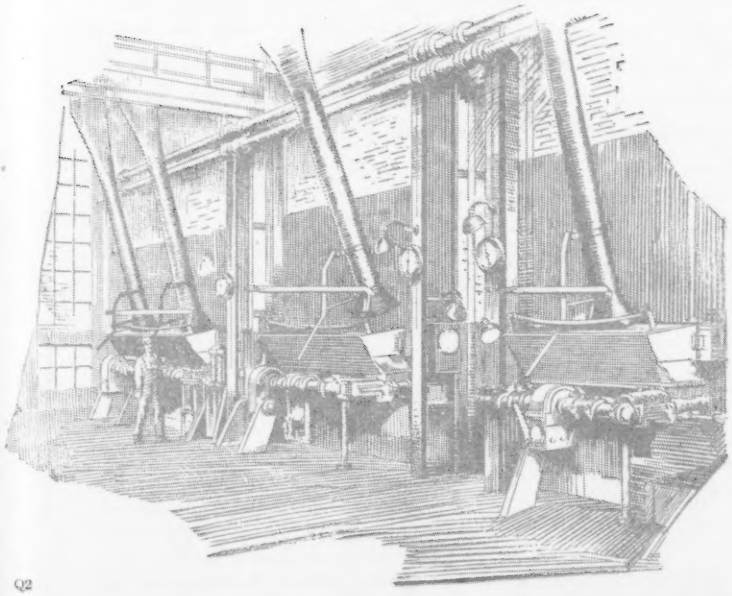

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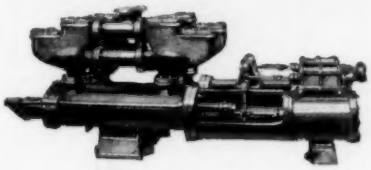
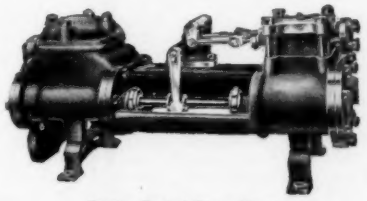
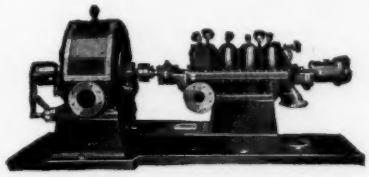


Pot Valve Boiler Feed Pump



Duplex Packed Piston Pump



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